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The Russian Federation and the International Space Station : leveraging russian space strengths to control its missile technology proliferation

Gloss, Lawrence E.

Monterey, California. Naval Postgraduate School

NAVAL POSTGRADUATE SCHOOL
MONTEREY, CA 93943-5101

NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

THE RUSSIAN FEDERATION AND THE INTERNATIONAL SPACE STATION:
LEVERAGING RUSSIAN SPACE STRENGTHS TO CONTROL ITS MISSILE TECHNOLOGY PROLIFERATION

by

Lawrence E. Gloss

September 1998

Thesis Co-Advisors: Craig Baldwin
Mikhail Tsypkin

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THE RUSSIAN FEDERATION AND THE INTERNATIONAL SPACE STATION: *LEVERAGING RUSSIAN SPACE STRENGTHS TO CONTROL ITS MISSILE TECHNOLOGY PROLIFERATION*

Lawrence E. Gloss
Lieutenant Commander, United States Navy
B.S., United States Naval Academy, 1988

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ABSTRACT

In an effort to stop the old Soviet space program from plunging into a cataclysmic spiral of illicit foreign sales of its ballistic missile technology, and also to prevent the Russian space infrastructure from imploding, the United States entered into a series of bilateral and multi-national agreements to work with, and to support the inheritor of the Soviet space legacy, the Russian Space Agency. This thesis discusses how a partnership with the Russian Federation and Russian Space Agency within the International Space Station can both act as an incentive for the Russians to prevent illicit proliferation of its space and ballistic missile technology and offer unique, viable operational, technical, and scientific advantages for the International Space Station and the United States. Alternative options to, and limits on, a partnership with Russia will also be presented and discussed.

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ATV Automated Transfer Vehicle

C&DH Command & Data Handling

C&T Communications and Tracking

CAV Cost Assessment and Validation

CRV Crew Return Vehicle

CSA Canadian Space Agency

EPS Electrical Power System

ESA European Space Agency

EVA ExtraVehicular Activity

FEL First Element Launch

FGB Functional Cargo Block [sic] (Functionalui Germaticheskii Block)

FY Fiscal Year

GDR General Designers Review

GFE Government-Furnished Equipment

GN&C Guidance, Navigation, and Control

GPS Global Positioning System

HTV H-II Transfer Vehicle

ILS International Launch Services

ISS International Space Station

JSC Johnson Space Center

KSC Kennedy Space Center

KHSC Khrunichev State Research and Production Space Center

MOU Memorandum of Understanding

MSFC Marshall Space Flight Center

MTBF Mean Time Between Failures

MTCR Missile Technology Control Regime

NAC NASA Advisory Council

NASA National Aeronautics and Space Administration

NRL Naval Research Laboratory

ORU Orbital Replacement Unit

PHC Permanent Human Capability

POP Program Operating Plan

RF Russian Federation

RSA Russian Space Agency

SE&I Systems Engineering and Integration

SM Service Module

SPP Science Power Platform

STA Structural Test Article

EXECUTIVE SUMMARY

Illicit Russian ballistic missile technology proliferation is a serious concern of the United States government. The Russian Federation's critical role in the International Space Station and its political and financial instability has long been a concern of NASA and other officials of the United States government. The lack of political stability and the economic uncertainty of the newly formed Russian Federation wrecked havoc on the old Soviet space program. There was a flight of specialized technical personnel from the Soviet space program, wages in the space industry were unpaid, and the political disintegration of the Soviet Union resulted in the fragmentation of the entire space industry of the old Soviet Union. Ballistic missile technology control was no longer centralized and illicit proliferation became a very real concern to Western powers.

Since the demise of the Soviet Union in the fall of 1991, the Western Powers, led most notably by the United States, have attempted to mitigate the destructive political, social, and economic forces which were dramatically undermining the Soviet military, economy, and social fabric. In an effort to stop the old Soviet space program from plunging into a cataclysmic spiral of illicit foreign sales of its ballistic missile technology, and also to prevent the Russian space infrastructure (launch facilities, ground stations, contractors, etc.) from imploding, the United States entered into a series of bilateral and multi-national agreements to work with, and to support the inheritor of the Soviet space legacy: the Russian Space Agency (RSA). The ultimate goal of the United States was to help stabilize the RSA as the Russian Federation (RF) government attempted to stabilize itself. A partnership with the Russian Federation involving the International Space Station can contribute to its viability and act as a successful leverage against the illicit proliferation of Russian space and ballistic missile technology.

There are several compelling strategic reasons to continue to work closely with the RSA in joint space endeavors, as well as to financially and technically support its space infrastructure. Depending on which performance measures one uses, RSA (and therefore RF) ballistic missile technology and supporting launch services are in many respects equal to, if not better than, those of its chief competitor, the United States. The simplified serial production philosophy of the Soviet Union with its emphasis on quantity left the RF well poised to quickly benefit from foreign ballistic missile technology sales. The RF inherited a robust satellite reconnaissance design and manufacturing capability that would also command a high level of interest on the international market. Drawing on the experience and expertise of the RSA, many nations and competitors can dramatically increase their space reconnaissance and communications capability in relation to the United States.

In point of fact, there is no real alternative to a partnership in the International Space Station (ISS) as proliferation control leverage with the Russians. The ISS represents a successful link between national security and space policies. It is not merely a giveaway to the Russians, nor should it be viewed as such: the Russians can and will render significant and highly credible and unique operational, technical, and scientific contributions to the ISS. The coupling of diplomatic control over proliferation as represented by the Missile Technology Control Regime (MTCR) with the operational, financial, and scientific incentive of participation in the ISS is the ideal manner in which to engage and monitor the Russians. Partnership in the ISS will serve as the most effective mechanism by which to control the dispersion of Russian scientific and technical expertise. There are added benefits to the ISS partnership as well.

The Proton Launch Vehicle has the heaviest payload capability currently being offered on the commercial market. In addition to the launch flexibility offered by the Baikonur Cosmodrome and economical reliability of the Proton launch vehicle, there are additional technical advantages in working with the RSA. Chief among the advantages are the RSA's pre-eminence in deep space communications, its extensive experience in logistical support and development of closed-cycle life support systems, and RF advanced material science technology. These are advantages the US government and commercial entities are successfully utilizing right now.

The Russian ability to launch massive payloads into a low-earth orbit (LEO) with the Proton launch vehicle will dramatically limit operating costs for the space station. Perhaps more importantly, Russian commitment to the ISS will provide a sustained and manageable outlet for Russian scientific and technical expertise. The Service Module and Functional Cargo Block (FGB) are the first two critical elements of the ISS to be built and launched by the Russians and they represent over one third of the total mass of the space station. These elements will provide early station-keeping power and living quarters and are the hub around which the rest of the ISS will be built.

A partnership with the Russians in the ISS offers real opportunities for controlling proliferation of Russian missile and space technology as well as providing unique and viable contributions to the operational and scientific success of the space station. How these opportunities are managed and pursued may well determine each country's space legacy for the next millenium.

I. INTRODUCTION

A. THE RUSSIAN FEDERATION AND BALLISTIC MISSILE TECHNOLOGY PROLIFERATION

There are valid concerns about whether or not the RF is committed to controlling its ballistic missile technology and whether or not it is capable of honoring its obligations to support the ISS. This chapter presents the basis of those concerns and how continued support to RF participation in the ISS is a viable and compelling option which the US should continue to pursue.

1. India, Iran, and Russian Ballistic Missile Technology

The recent headlines of American space companies illegally transferring ballistic missile technology to the Chinese highlight an eventful and alarming few months. Space Systems/Loral provided a report to the Chinese on the causes of an earlier missile failure without first consulting with federal officials.[1] Equally alarming proliferation news comes India.

The series of nuclear detonations set off by India in May only confirmed what arms control and missile technology

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[1]Gerth, Jeff. "Satellite Maker Gave Report to China Before Telling U.S..," *New York Times*, 19 May 1998, 1.

proliferation experts had always suspected: India is intent on establishing itself as a legitimate nuclear power. India has been greatly aided by the RF. In March of 1997, the Russian Space Agency (RSA) agreed to start supplying India with rocket boosters and related missile technology.[2] In all probability, qualified Russian personnel aided the Indians in weapons and program management, helping the Indians avoid costly and dangerous missteps along the way to successful detonation of their nuclear devices. The US reprimanded the RF in 1993 for selling missile technology to New Delhi and violating the Missile Technology Control Regime (MTCR) accords.[3] There is a long heritage of military cooperation between India and the Soviet Union (and now the RF).

The Russian reaction to the Indian nuclear detonations was, interestingly enough, atypical. A week before the Indian detonations, Russian Federation President Boris Yeltsin drafted an urgent document calling for the consolidation of authority over all issues of missile and space technology proliferation under the sole cognizance of

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[2]Griffin, Jennifer, Untitled, Voice of America (VOA) News Report, 26 March 1997.

[3]Baksian, Douglas, *India Satellite Launch,* VOA News Report, 29 August 1997.

the Russian Space Agency.[4] Yeltsin has clearly indicated he, in fact, had foreknowledge of the nuclear blasts. It is suspected that Yeltsin made this announcement to diffuse expected international criticism about Russian support to the India nuclear detonations.

That Yeltsin categorically addressed the full range of space and proliferation concerns by granting the RSA such sweeping technologic and managerial oversight over all Russian space industries is singularly remarkable. The RSA will now have authority over, and authority separate from, the RF Defense Minister and the Federal Service Security Director.[5] The consequences are extremely significant. In the endgame of proliferation control, the RSA now has immense responsibilities; it must not only manage the Russian space industry, but Russian technology proliferation concerns as well.

The RSA has inherited a significant proliferation challenge, and not just as far as the Indians are concerned. Iran is a leading customer of Russian ballistic missile technology, as well. Among the Russian firms alleged to have aided the Iran missile effort are the All Russian

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[4]Golotyuk, Yuriy, *Russia: Space Agency to Acquire 'Special Service' Arm.* FBIS translation of Moscow Russkiy Telegraf, 15 May 98.

[5]Ibid.

Scientific Research Institute of Technical Physics, the All Union Scientific Research Institute of Experimental Physics (Arzamas-16), and the Moscow Aviation Institute.[6] Russian expertise in missile guidance technology, propulsion technology, and communications support are the most readily exportable technologies. Regrettably, the Russian Federation has much to offer would-be ballistic missile powers.

2. Valid Arguments

Russians are currently involved with several high profile technology transfer issues. Russian expertise in delivery vehicles for Weapons of Mass Destruction (WMD) is widely known and its nuclear technology is being exported to India and Iran as these countries try to develop their nascent nuclear power industries. Russian intelligence officers were allegedly responsible for smuggling weapons-grade fissile material into Germany in August of 1994.[7] Perhaps even more alarming is the story of 50 Russian rocket scientists being apprehended on their way to North Korea.[8]

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[6]Odessey, Bruce. *Sites in 5 Countries Identified With Weapons Proliferation,* USIA, 30 Jun 97.

[7]Eggleston, Roland. "Russia: Were Intelligence Officers Involved In Plutonium Smiggling?", *Radio Free Europe/Radio Liberty,* 2 Jun 1997.

[8]U.S. Congress, Office of Technology Assessment, *Proliferation and the Former Soviet Union*, U.S. Government Printing Office, September 1994, pp. 32-33.

Russia is a formidable exporter of relatively sophisticated missile technology and any effort to channel its proliferation potential towards benign commercial enterprises should be actively encouraged. Nurturing RSA participation in the ISS may prove to be the most effective, if not the only way, to control the proliferation of Russian space and missile technology.

B. THE RUSSIAN FEDERATION AND THE INTERNATIONAL SPACE STATION

1. Postponement of the Functional Cargo Block (FGB)

The M. V. Khrunichev State Space Science and Product Center (KHSC) announced the long-rumored news in early April 1998.[9] Despite the infusion of over $400 million dollars by the United States and despite being under the lead management of the National Aeronautics and Space Administration (NASA), the Russian Federation (RF) and the Russian Space Agency (RSA) postponed the June 28th launch of the Functional Cargo Block, known by its Russian acronym, FGB. The FGB is the first element of the ISS scheduled to be launched.

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[9]Dmitriyev, Petr. "Rocket Builders Break Their Silence. Space Station Assembly Finally Postponed Officially," *Moscow Nezavisimaya Gazeta,* April 7 1998, page 2.

The schedule slippage was attributed to the inability to launch the Russian Service Module in December 1998. This module is necessary because the FGB cannot exist for an extended period of time in orbit without its refueling and station-keeping capability. The RF failure to promptly pay for the service module directly effects the space station's life support and re-boost capability. There are other financial concerns about the RF and RSA as well.

The RSA has still not received almost $45 million from last year's government budget and it has received only $8 million of its estimated $340 million budget for this year.[10] The postponing of the launch of the FGB may very well justify a complete reassessment of the scope and nature of the relationship between the U.S. and RF in the ISS. Indeed, there are many scientific, technical, and management concerns about RF participation in the operational, technical and management architecture of the ISS.

The critical role played by the Russians in the International Space Station has long been a concern of NASA and other officials of the U.S. government. The lack of political stability and the economic uncertainty of the newly formed Russian Federation wrecked havoc on the old

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[10]Aerospace Daily, *Russia's Station Status On the Line Over Service Module Delay,* The McGraw Hill Companies, Inc, 7 May 1998, p. 211.

Soviet space program. The RF space infrastructure experienced a severe flight of specialized technical personnel and intellectual capital from the Soviet space program, wages in the space industry were unpaid, and the regional break up of the Soviet Union resulted in the splintering and fragmentation of the entire space industry of the old Soviet Union. The US must constructively engage the inheritor of the Soviet space program, the Russian Space Agency. The RSA can offer the ISS and the US distinct technical space advantages as well as an avenue through which to monitor missile technology proliferation.

There are many concerns about working with the RSA in any space endeavor whatsoever. Only a year ago US congressional opponents of the International Space Station initiated a resolution to end US participation with the Russians in the Space Station.[11] Despite the estimated cost of over $17 billion (with current projections running towards $21 billion), some argued that the United States and NASA should run the entire program, without any foreign

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[11] U.S. Congress. House. 1997. *To terminate the United States Participation in the International Space Station program.* 105th Cong., 1st sess., H.R. 1831 1H.

participation at all. The recent release of the detailed Chabrow Report also supports these arguments.[12]

2. The Chabrow Report

The Cost Assessment and Validation Task Force (CAVTF), headed by Jay Chabrow, an aerospace consultant, provided an independent review and assessment of the ISS and the Russian role within it. The Chabrow Report addresses NASA's late February acknowledgement that the ISS is over its authorized budget ceiling by $3.7 billion. The cost overruns are attributed to RF production and testing delays of the Service Module and the FGB.[13] The Chabrow Report cites RF participation within the ISS architecture as a major program risk.

Of the six key findings of the Chabrow Report, the fourth directly addresses Russian contributions to the space station. The Chabrow Report states that the schedule uncertainty associated with Russian implementation of joint partnership agreements is the major threat to the ISS

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[12]In September 1997, NASA established a Cost Assessment and Validation task Force to conduct an independent review and assessment of the cost, schedule, and partnership performance of the ISS. The task force was headed by Mr. Jay Chabrow. His goal was to provide advice and recommendations for improvement of the ISS management structure.

[13]John C. Henry, "Russian Financial Woes Put Space Station in Jeopardy," *Houston Chronicle,* 23 April 1998, 1(N). Also refer to [http://www.chron.com:80/cgi-bin/auth/story.mpl/content/chronicle/nation].

Program.[14] The inability of the Russian government to pay its personnel and maintain its space launch capability directly impacts the ISS program schedule. In point of fact, one of the closing recommendations of the Chabrow Report is for the U.S. to invest in developing its own permanent propulsion and logistics capabilities in order to mitigate the criticality of reliance on the RF for this support.[15] The Chabrow Report focused concerns about the costs and viability of the space station.

3. Valid Arguments

Opponents of working with the Russians and the RSA within the current coalition of the ISS do, in fact, voice very credible concerns. Senator Barbara Mikulski (D-MD) says that she is running out of patience with the Russians. She stated that the Russians were invited to participate in the ISS largely as an inducement to redirect their technical expertise towards commercial purposes and limit technology proliferation. She is worried that Russian inability to support the Space Station may suggest that little or no progress is being made in the technology proliferation realm

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[14]Report of the Cost Assessment and Validation Task Force on the International Space Station, NASA Advisory Council, [http://www.nasa.gov/cavtf/cavtf 1.html], page 4.

[15]Ibid, 20.

as well.[16] Mikulski questions whether Russia can be counted on for full and regular support to the ISS when its technical and management capability, not to mention its political will, are so highly questionable. The schedule slippage of the FGB is only one of many concerns.

The problems with integrating the FGB into the ISS are suggestive of all the ISS-support problems associated with the RF. First, NASA purchased the module outright from KHSC for $190 million. NASA then contracted out module upgrades to Boeing. Boeing then promptly contributed the improved module to the space station on behalf of the RSA and the RF.[17] Initial Russian contributions to the ISS have been problematic at best and far from certain endeavors.

Before addressing other legitimate concerns of RF ballistic missile technology proliferation and support to the ISS, a thorough assessment of the RSA and Russian space capabilities must be done. Knowing the origins and strengths of the Russian space program will provide a more balanced perspective on joint cooperation between the United States and the Russian Federation in the ISS. What are the origins of the Russian space program, its strengths,

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[16] Henry, 1(N).

[17] *International Partner Cooperation - Russian Space Agency,* [http://station.nasa.gov/reference/status/rsa.html], page 1.

origins of the Russian space program, its strengths, weaknesses, and potential?

C. THE BEGINNING OF THE BEGINNING OR "IS THE GLASS HALF FULL OR HALF EMPTY?"

1. Common Interests

The fall of the Communist Party in the former Soviet Union permanently altered the paradigm on which US national space policy was formed. Moving beyond a broad spectrum of diplomatic and military confrontation and containment, the US is now working closely with the Russian Federation in endeavors previously unimaginable. Be it reciprocal fleet visits to each country's naval bases, mutual support for NATO enlargement, seeking support for UN efforts in the Balkans, or multi-corporation, multi-national efforts to tap the seemingly limitless natural resources of countries of the Former Soviet Union (FSU), the United States and the Russian Federation are increasingly likely to constructively engage each other in military, economic, and technological matters.

These shared interests extend well beyond the merely terrestrial. After forty years of intense, government-directed competition in space exploration, the United States and the Russian Federation remain preeminent in the field of space capabilities as well as in the development and production of space-related technologies. Additionally, the European Space Agency (ESA), Japan, and China also have increasingly capable space programs. The ESA and Japan are also lead partners with the US and RF in the ISS. Space may indeed be mankind's final frontier, but for the United States and the Russian Federation the exploration of space may well prove to be the ultimate proving ground for each country's 21st century legacy.

2. Common Concerns

The current setting for these two country's efforts in the joint space coalition environment of the ISS could not be fraught with more anxiety and more consternation. The Space Station "Mir" has in fact become the "Troubled Space Station Mir." From oxygen system failures, onboard fires, power outages, misplaced cables, computer failures, overworked cosmonauts, and things that go "bump!" in the night, Mir has become the focus of arguments against Russian participation in the ISS. Often lost in these arguments is the fact that Mir is the record holder for longest continuously manned spacecraft and operating over 6 years past its original life span. In fact, Astronaut David Wolf, originally very skeptical of the Mir space station, became an advocate of the Mir's capabilities. In May of this year, he went so far as to state that the Mir space station program is a brilliantly conceived program.[18] Given its age and the harsh environment of space, it is not surprising that such a complex system experiences such frequent mechanical problems in the severe environment of space.

Today Russia is a country marked by unpaid wages, unpaid and uncollected taxes, dubious privatization, a burgeoning Mafia, and rampant corruption and poverty.[19] There has also been a pronounced flight of human intellectual capital from the RSA. Working with the Russians and the RSA is certainly problematic under the best of circumstances. However, Russian and the RSA have certainly demonstrated their technical and managerial resiliency. Their long track record and potential to make solid contributions to the space achievements well warrant a role for the RSA in the ISS. If this role can also be used as leverage to maintain continuity on Russia's proliferation control efforts, then the argument becomes more intriguing - and more compelling.

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[18]Philip Chien, "Space Jalopy," *Popular Mechanics*, May 1998, 99.

[19]The Economist, The Endless Winter of Russian Reform (Essay), July 12 1997, page 2.

D. COMPELLING REASONS

1. Shoring up the Remains

Since the demise of the Soviet Union in the fall of 1991, the Western Powers, led most notably by the United States, have attempted to mitigate the destructive political, social, and economic forces which were dramatically undermining the Soviet military, economy, and social fabric. In an effort to stop the old Soviet space program from plunging into a cataclysmic spiral of illicit foreign sales of its ballistic missile technology, and also to prevent the Russian space infrastructure (launch facilities, ground stations, contractors, etc.) from imploding, the United States entered into a series of bilateral and multi-national agreements to work with, and to support the inheritor of the Soviet space legacy, the Russian Space Agency (RSA). The ultimate goal of the United States was to help stabilize the RSA as the RF government attempted to stabilize itself. Facilitating the participation of the RF in the ISS may be the last mechanism by which Russia's missile technology proliferation may be tracked and controlled.

2. Strategic Perspective

There are several compelling strategic reasons to continue to work closely with the RSA in joint space endeavors, as well as financially and technically support its space infrastructure. Depending on which performance measures one uses, RSA (and therefore RF) ballistic missile technology and supporting launch services are in many respects equal to, if not better than, those of its chief competitor, the US. The simplified serial production philosophy of the Soviet Union with its emphasis on quantity left the RF well poised to quickly benefit from foreign ballistic missile technology sales. The RF inherited a robust satellite reconnaissance design and manufacturing capability that would also command a high level of interest on the international market. Drawing on the experience and expertise of the RSA, many nations and competitors can dramatically increase their space reconnaissance and communications architecture capability in relation to the United States. It is certainly in the best interests of the United States to be intimately involved with the management of RF space capabilities, technologies, and policies to any extent that it can be. The US should not maintain a hands-off, wait-and-see policy regarding the Russian space program and its ballistic missile technology, the stakes are too high. Ballistic missile technology proliferation concerns are indeed enough justification to re-organize the ISS to integrate the best capabilities of the RF and RSA.

3. Commercial Perspective

The RSA became the owner of highly reliable launch vehicles in the Proton and Soyuz rockets and it has also assumed financial and management responsibilities for the world's most extensive launch facilities at the Baikonur Cosmodrome in Tyuratam, Kazakhstan. Given the proliferation of commercial space communications demands, many foreign and US firms (and the number increases daily) are eager to take advantage of the heavy-lift capability of these RSA launch vehicles. These same launch vehicles are easy to maintain, highly efficient, and with a ten-year reliability rating of over 93 percent for the Proton, are the most reliable in the global space arena. Because the Proton's heavy lift capability enables it to carry more payload weight per pound of fuel, it is able to realize dramatic economies of scale in orbiting costs. The payload to fuel advantage and benefits resulting from the Proton's serial production efficiencies have the potential to result in savings of as much as 20 percent to 40 percent over prevailing Western launch prices (please refer to the table on page 67).[20] This distinct cost advantage has not been lost on the international space market; it is widely acknowledged that RSA possesses one of the most, if not *the most*, highly economical and efficient launch vehicles in the Proton.

E. A CLEAR REALITY

The reality is clear. The guidelines of the Missile Technology Control Regime (MTCR - to be discussed in depth in Chapter V, starting on page 81) regarding the control of technology proliferation provide the legal and diplomatic mandate on which to ensure Russian compliance with controlling its missile and space technology proliferation. Complementing the diplomatic tenets of the MTCR is the practical results of partnership within the ISS; the RSA lies in the critical path for any successful efforts to support the Space Station Mir and the ISS. Fully one third of the orbiting mass of the ISS will either be made in Russia or launched from the Baikonur Cosmodrome. The operational and management scope of the ISS entails sophisticated financial and technological commitments from the three major space agencies (NASA, RSA, and the European Space Agency, ESA) as well as billion dollar contractual

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[20]Peter B. De Selding, "Proton Pricing Spurs Complaints," *Space News*, 9 January 1995, 1.

obligations from hundreds of contractors and sub-contractors from all over the globe.

The heavy lift capability of the RSA Proton will figure prominently and critically in all phases of heavy-lift launch support. At a cost savings of up to $11,000 per pound over the space shuttle, the Proton and Baikonur offer the ISS management many degrees of operational freedom at the lowest price and highest reliability. The RSA is and will continue to be a significant partner in the operational and managerial success of the ISS.

Within the operational construct of the ISS space coalition, there is an obvious need to fully understand all the technical strengths of the RSA space program. To not be cognizant of these strengths, to be unaware of program management vulnerabilities, could well prove to be disastrous for the timeline, technology, and budget of the ISS.

F. CONCLUSION

The historical precedents and most notable achievements of the Soviet space program and its RF descendant, the Russian Space Agency, warrant closer examination. Careful analysis will determine the most efficient methodology for identifying, assessing, and integrating the RSA's distinct technological, managerial, and operational advantages into the management and operational infrastructure of the International Space Station Alpha. But there are programmatic and policy hazards in doing so.

The alternatives to the ISS partnership are limited. Withdrawing financial support for the Russians in the ISS would result in a severe disruption to the ISS schedule. Replacing the heavy-lift capability of the Proton would be problematic at best; no other launch vehicle offers the range of lift capability at such an inexpensive rate (refer to page 67 on cost comparisons). Because the capabilities offered by the Russians are so extensively incorporated into the ISS, the entire scope and design of the space station would have to be thoroughly redesigned if the Russians were no longer allowed to participate.

This paper will also present the areas where US governmental and commercial space ventures are currently benefiting from certain RSA technical, operational and managerial capabilities and innovations. There is cause for optimism in working with the RF and RSA; Russia has the technical and scientific potential to make unique, significant contributions to the ISS. This paper will discuss where the technical and scientific potential of the RF and RSA can best be realized. To be sure, the path ahead is fraught with concern. But now, more than ever, the institutional leverage required to manage the Russian space industry and control ballistic missile technology proliferation appears in place. This paper advocates how to use that leverage for the ISS and the US as well.

Yeltsin's decision to place responsibility for technology proliferation control in the hands of the RSA is added incentive for the US to form as close a partnership within the ISS as possible. The issues presented in this paper will serve as the criteria on which to assess the ISS partnership with the RSA and to validate the health and viability of the Russian heavy-lift launch vehicle, the Proton, and the Russian Federation's premier launch facility, the Baikonur Cosmodrome. These same issues will demonstrate that the RF space program and industry do indeed offer distinct advantages for joint US and RF participation in the Space Station and that Russia has enormous potential to render unique contributions to the success of the International Space Station. Most significantly, to minimize the potential for illicit missile technology proliferation, joint participation in the ISS is fully justified, if not fully required. In order to protect and ensure its own space legacy, the US and NASA must maintain a close relationship with the RF space program.

II. EARLY HISTORY OF THE SOVIET SPACE PROGRAM

A. THE GERMAN V-2 ROCKET PROGRAM

1. The Fight for German Expertise and Personnel

The origins of the current RF space program can be readily traced back to the closing years of World War II. From the October 1957 orbiting of Sputnik and the successful launch and recovery of Yuri Gagarin in 1961 through the current Space Station Mir of 1998, unique Soviet circumstances and intense competition with, and paranoia of, the United States drove the organization and mission of the Soviet and RF space programs. By describing and discussing the historical aspects of the old Soviet space program, as well as gaining insight into its technical culture and ethos, one can best understand the nature of the current RSA space program. Given the historical and technical underpinnings of the early Soviet space program, it will then be a natural consequence to determine the optimum path for future mission successes and substantial and productive scientific gain. This path will point to the way in which a joint space coalition between NASA and the RSA can best leverage the most compelling technological advantages of the Russian space industry, while also ensuring proper attention is focused on RF ballistic missile technology proliferation.

The origins of the Soviet Union's space program emerge from the conflict of the Second World War and they are quite similar to those of its Cold War competitor, the United States. In fact, the birth of both of the Soviet Union's and the United States' space programs can be traced to the German Peenemunde V-2 rocket program. Peenemunde was a German rocket design, test and evaluation facility and live missile range on the Baltic coast. The lead rocket designer on the V-2 was the world famous Wernher Von Braun. During World War II, the strike capability of the V-2 rocket justifiably caused British Prime Minister Winston Churchill much anxiety.

The V-2 was truly a revolutionary ballistic missile. Under the design and supervision of Von Braun and Walter Theil, the V-2 had the lift capability to carry a one metric ton payload over 150 miles; London was in striking distance. It was the first missile to successfully use a turbo-pump and three-axis stabilized guidance system.[21] Once Churchill tipped off Stalin about the capabilities and whereabouts of the V-2 test facility, the Soviets were determined to find out all they could about this technology, if not control it themselves.

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[21]James Harford, *Korolev: How One Man Masterminded the Soviet Drive to Beat America to the Moon* (New York: John Wiley & Sons, Inc, 1997), 65.

In their sweep across Eastern Europe the Soviets easily captured Peenemunde and much of the supporting scientific research personnel and resources. Von Braun ensured he would be captured by the US by giving US forces his location and, more importantly, by also giving tantalizing insight into the nature of his research.[22] The Soviets not only captured Peenemunde but also some 170 scientists, including Helmut Grotrupp, the designer of the guidance system of Von Braun's V-2 rocket.[23] The treatment the German scientists and their families received from the US government starkly differed from the treatment they received from the Soviets. By all accounts, the Soviets wrung all expertise out of the Germans, most notably in the areas of instrumentation and test equipment. Once the Soviets were convinced the Germans held no further value to their nascent ballistic missile program, they were repatriated back to (then East) Germany. By 1954, the last contingent of German scientists had returned to their Fatherland.[24] In contrast to the Soviets, the U.S. allowed and encouraged continued German participation in its missile program for as long as the

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[22]Brian Harvey, *The New Russian Space Programme (New York:* John Wiley & Sons, Inc, 1996), 12.

[23]Ibid.

[24]Harford, 89-90.

Germans themselves wished to contribute. By the end of World War II, the US and Soviet Union were both employing and competing for German rocket scientists.

2. Soviet Motivation for Ballistic Missile Technology

The Soviet drive and almost frenetic need for technological breakthroughs in ballistic missile capabilities was all too clear; such technology would revolutionize their nuclear and non-nuclear strike capability. German V-2 rocket technology was vitally required to jump-start each country's nascent ballistic missile program. The early driving impetus in ballistic missile technology for the Soviet Union was the absolute need to develop a transportation vehicle with a significant heavy-lift capability; Soviet bombers had neither the lift capability nor the strike range to effectively threaten or deter would-be enemies, particularly the US. The Soviets issued a decree calling for the development of ballistic missiles on 13 May 1946.[25] The ballistic missile arms race had officially begun.

In essence, the lack of long range lift capability meant that the Soviet Union did not possess the long-range nuclear strike capability of its chief competitor, the United States. The Soviet Union's hydrogen bomb was far too massive, far too heavy, and it simply required an extremely large, powerful rocket to carry it. Having a long range, nuclear strike capability would go a long way towards assuaging the Soviet anxiety about combating another invasion. This deficiency existed until the successful design and launch of the Soviet R-7 rocket.

The R-7 was Sergei Korolev's brainchild. On 21 August 1957, an R-7 carried a dummy warhead an intercontinental distance of over 4,000 miles.[26] In grooming their program for heavy-lift rocket launches to carry the hydrogen bomb over intercontinental distances, the Soviet Union serendipitously prepared itself to naturally transition to manned space flights. The significant thrust ability of the R-7 could also be easily used to launch much lighter satellites and spacecraft into outer space. If the rocket had enough thrust for the Soviet Union's massive hydrogen bomb, it could also be used to support space flight and space exploration. Launching a cosmonaut with all the required ancillary support equipment into orbit was a natural consequence of the USSR's early emphasis on heavy

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[25]Ibid.

[26]Harford, 91.

lift rockets.[27] The emerging Cold War rivalry between the US and the Soviet Union influenced the very design and production philosophy of Soviet space managers. The first satellite placed in orbit, Sputnik, represents this production philosophy (see Figure 1).

B. SPUTNIK HO!

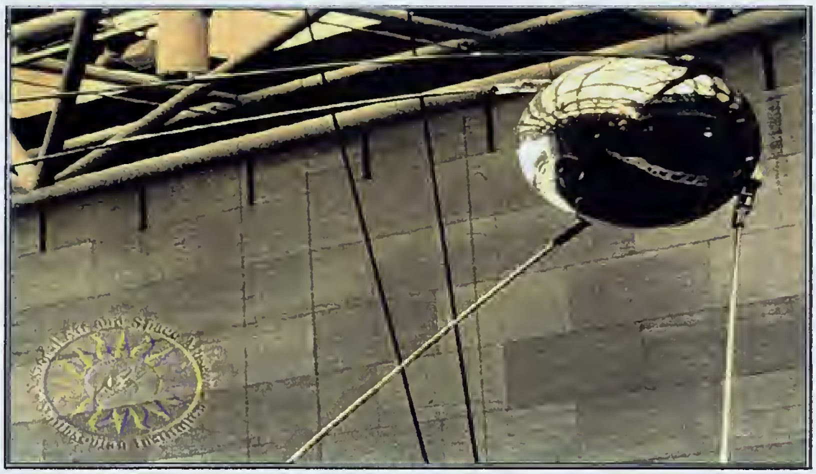

Figure 1. The Sputnik Satellite. (Image of Sputnik I model courtesy of National Air and Space Museum)

In an effort to inundate and impress putative Western competitors, Soviet space managers placed an absolute premium on production speed and quantity of their space

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[27] U.S. Congress. Office of Technology Assessment. *US-Russian Cooperation in Space*. Washington, D.C.: Government Printing Office April 1995, 26.

products. They wanted to launch as many rockets, to place in orbit as many satellites and cosmonauts as possible - in absolutely minimal time. They also programmed an emphasis on immediate replenishment or replacement of space personnel or space resources.

The early spacecraft of the Soviet space program were not designed to long endure the rigors of the space environment. After launching Sputnik in October 1957, they launched three others within seven months as well as attempting nine moon launches over a two and a half year period from October 1957 until April 1960.[28] Because the Soviets opted for shorter design life spans for all of their satellites, minimal replacement time was an absolute imperative of the supporting space architecture. It is highly doubtful that the Soviets correctly anticipated the rapid obsolescence of many of today's space systems. There priority was to place satellites in orbit as quickly as possible, certainly before the US. In any case, the end result of the government's emphasis to replace failing satellites in minimal time was the Soviet Union's remarkable ability to streamline the production process and launch replacement satellites in as little as 48 hours. This is a

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[28]Harvey, 33.

technological accomplishment still unmatched by any other space agency on earth.

C. TECHNICAL CULTURE AND ETHOS

1. Brute Force and Quantity over Quality

The competitive political and military environment between the Soviet Union and the United States resulted in the Soviet Union placing the highest priority for its early space program on heavy-lift launches and extremely responsive, streamlined production processes. With these two aspects dominating the scientific and technical culture of the Soviet space program, what were its most conspicuous achievements in the early exploration of space?

The early efforts which culminated in the launching of Sputnik I demonstrate the sense of priorities of the early Soviet space program. The original plan was to orbit a 1.5 ton scientific research satellite onboard an R-7 launch vehicle. However, in the interest of speed and design ease, Sergei Korolev, the director of the division for long range missiles[29] within the Scientific Research Institute, opted to place into orbit a much simpler spacecraft. Sputnik was a simple, spherical radio transmitter that weighed a mere 83

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[29]Ibid, 14.

kilograms (about 180 pounds).[30] When the "beep, beep, beep" of Sputnik's transmitted signal was received on earth, the drive to place satellites in orbit for the express purpose of the exploration of space had officially begun. The next satellite launch of the Soviets, Sputnik II, showed the earnestness of the Soviet program.

Sputnik II weighed more than ten times the amount of Sputnik I and carried a dog as a passenger. The Soviets launched Sputnik II a mere 30 days after Sputnik I. The emphasis on simple design and serial production enabled the Soviets to stake an early lead in the space race with the United States. These aspects of the technical and engineering culture of the Soviet space program carried over into the Soviet's manned spaceflight efforts.

2. Staying with the Tried and True

The Soviets rarely strayed from the tried and true: in fact, earlier design commitments long dictated subsequent design considerations. The progress of Soviet space technology proceeded carefully along an evolutionary path, rather than a revolutionary path. Because the early Soviet space program enjoyed the benefits of the heavy-lift capability of rockets such as the R-7, there was far less of

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[30]Ibid, 22.

a design premium placed on component weight reduction and miniaturizing electronics. Even now, Russian space electronics are extremely crude and cumbersome by Western space standards. The Soviets used vacuum tube technology long after the U.S. had transitioned to solid state devices.[31] There simply was no concerted effort, no incentive, to incorporate weight-reducing designs into proven systems. There was a systematic dearth of innovation in the Soviet Space program.

The simple approach clearly applied to spacecraft design as well. Designing a spacecraft to carry humans and successfully re-enter the earth's atmosphere was critical. If the heat shields were not properly designed and placed on the re-entry vehicle, the craft could burn up upon re-entry. The early American efforts involved numerous wind-tunnel tests of a bullet-shaped re-entry vehicle. In addition to determining the correct layering and placement of heat shields, the American design required a meticulously executed re-entry; the design of the heat shields was optimized for a specific flight path. Flying a bullet-shaped re-entry vehicle in one specific direction to optimize heat shield design required an extremely precise and accurate design. As often as not, the Soviet space

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[31]Office of Technology Assessment, 26.

program bypassed, rather than mastered, precision science requirements.

Korolev approached the same problem in a far different fashion. He opted to design the re-entry vehicle as a perfect sphere and heavily weighed one face (the leading edge) of the spacecraft with the protective heat shields. The gravitational vector of the earth would always act on the heavier half of the re-entry vehicle. In effect the gravitational force of the earth would direct the motion of the spacecraft, rather than cosmonauts onboard. Korolev would let the laws of physics and gravity correctly "pull" the spacecraft back into the earth's atmosphere. The concept was charming in its simplicity and it worked flawlessly.[32]

There were other stark differences between the early space programs of the Soviet Union and the United States. The Soviets opted for territorial landings vice landings at sea. The reasons for this stemmed from the Soviets lack of maritime wherewithal and an almost paranoid desire to maintain the strictest sense of secrecy about their space efforts.

While its simplicity and speed distinguished the science of the early Soviet space program, and while the manufacturing process emphasized quantity over quality, the economic underpinnings of the Soviet space program are harder to fathom. More insight can be gained into the later challenges to the RSA by examining the financial underpinnings of the early Soviet space program.

3. Early Soviet Space Budget

In the Soviet Union there was a single space budget that supported all military space efforts; there were no purely civilian space initiatives.[33] In fact, both the nominally civilian and military space entities largely shared the same infrastructure, design bureaus and personnel. Because no truly independent and functional legislature was ever established in the Soviet Union, the Communist Party directly shunted money on an ad hoc basis from the government to individual design bureaus. The economics of communism and the vagaries of the Soviet government did not allow for the use of traditional R&D and procurement financial models. A Communist Party order was sent from the Politburo to the "official" governmental body, the Council of Ministers, to build a specific space system. Money was then appropriated and allocated to the Ministry of General Machine Building. This Ministry was responsible for

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[32] Ibid, 35.

deciding which design bureau would best fulfill the system specifications. The military had the sole power of accepting or rejecting an entire missile system before it ever went into production. The lack of independent oversight of the Soviet space program by civilian authorities ensured that the military dominated all aspects of design and production of Soviet space capabilities.

The original funding would also include obligations for testing and evaluating the particular space system. It is important to note that if the tests went well, the Military Industrial Commission would initiate large-scale production. There was absolutely no hint of independent, outside control (civilian or military) of testing, validating, or management oversight whatsoever. Once funding was allocated to the appropriate design bureau the system went forward and was sustained by its own momentum. There was no life cycle cost management in the Western sense. Programs rarely ended; they were often folded into emerging programs which built upon the earlier strengths and successes of preceding programs.

D. CONCLUSION

Because the climate and nature of communism in the Soviet Union system did not readily allow for, let alone

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[33]Office of Technology Assessment, 26-27.

encourage, a process of continual innovation and improvement, a previously approved space system was often adapted to other space objectives with little or no modifications to the original blueprints. However, the original requirements and design goals usually ended up significantly modified, or "cross-decked". The spacecraft design that carried Yuri Gagarin into orbit was later modified to serve as a photo-reconnaissance platform. Soviet space engineers were able to "cross-deck" system designs for multiple missions with minimal engineering re-work and minimal costs. This is a constant theme of the technical culture of the early Soviet space program. This meant that modified, workable systems were usually fielded in relatively short time periods.[34] The overall mindset of Soviet Space officials can be summed up as emphasizing quantity over quality, and exhibiting an overwhelming desire to always beat the US.

The early origins of the Soviet Union's Space Program can be traced historically to the end of World War II and, politically, to the growing, world-wide competition with, and paranoia of, the US. The economic foundations of the space program are difficult to credibly document, but the Soviet Union probably outspent the United States in relative

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[34]Ibid, 27.

space expenditures by a ratio of 3:2, with over 65 percent of these expenditures going to military space applications, representing approximately .29 percent of the GNP.[35] The production philosophy was unsophisticated and made its mark in volume, but not quality or sophistication. From organizational management, to scientific and technical support, to budgetary commitments, the entire span of Soviet space activities was dominated by, and completely subordinated to, military priorities and applications. The Russian Federation inherited unique capabilities from the Soviet Union.

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[35]These assesments are culled from the OTA report on the Russian space program. Refer to pages 29 to 37.

III. THE RUSSIAN SPACE AGENCY

A. ORIGINS OF THE RUSSIAN SPACE AGENCY

1. The Demise of the Soviet Union

The Russian Space Agency was established in a political and social environment filled with turmoil and danger. How the Russian government of Boris Yeltsin confronted the challenge of stabilizing the remains of the Soviet space program speaks volumes of the politics and economics in Russia, both then and today. Understanding this challenge will provide insight into the resiliency of the Russian space program.

Upon the dissolution of the Soviet Union in the fall of 1991, the old Soviet space program found itself as fragmented as the newly organized Commonwealth of Independent States (CIS). The flagship launch complex at Baikonur, Kazakhstan was no longer readily available; it belonged to Kazakhstan and not Russia. The former Soviet Union's premier launch facilities were not immediately at the disposal of the RSA. The primary design and manufacturing facility of NPO Yuzhnoye and its 30,000 employees were outside of Russian sovereignty, in Ukraine. The loss of NPO Yuzhnoye and its personnel represented more than just a loss to the space manufacturing capability of the RF.

Because NPO Yuzhnoye also produced remote sensing, intelligence, and weather satellites, the loss of these technologies was keenly felt by the RSA. Fully one third of the spacecraft command and control centers were in Georgia, Kazakhstan, Ukraine, and Uzbekistan. Sensitive space surveillance facilities were located in Ukraine, Azerbaijan, Latvia, Tajikistan, Turkmenia, and Armenia.[36] Because of the widespread dispersion of vital elements of the old Soviet space program, the RSA of the Russian Federation first had to retrench and reorganize its space activities before resuming an active presence in its former space endeavors.

2. Two Steps Backwards

In an effort to recombine the former elements of the Soviet space program, the Russian Federation spearheaded an effort to form a cooperative relationship among space entities of the CIS. In 1992 ten members of the former Soviet Union agreed to support a unified space program for the CIS. This agreement never produced tangible, successful results; the governments of its constituent members were

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[36]Office of Technology Assessment, 27.

overwhelmed by the traumatic responsibilities of transitioning to new governing bodies to properly focus their energies and resources on space initiatives. In fact the Russian Federation inexorably assumed the dominant lead in space activities of the former Soviet Union, as much by default as by design.[37] Frustrated by officials of the Kazakhstan Space Agency and its control of the Cosmodrome at Baikonur, Russia opted to lease the launch facility for at least the next twenty years.

3. One Step Forward

Many of the command and control stations outside of Russia proper have gradually been taken offline and replaced with space-based auto-relay satellites.[38] Russia is also leasing the supporting test ranges in Kazakhstan. Upon the dissolution of the Soviet Union, Russia took the lead in recombining the most important elements of the former Soviet space program into its own area of responsibility. The next phase in the emergence of the RSA involves the powerful role politics and economics played in stabilizing the resources and focusing the management of the RSA and the

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[37]U.S. Congress. Committee on Science, Space, and Technology, *Space Activities of the United States, Soviet Union, and Other Launching Countries: 1957-1993,* Washington, D.C.: Government Printing Office April 1994, 106.

[38]Office of Technology Assessment, 129.

supporting Russian space infrastructure. These efforts all came together in an entirely new organization, with a new charter and a growing commitment to a new, Western-style business approach.

B. POLITICS AND ECONOMICS

1. A Legislative, Vice Military, Mandate

President Yeltsin created the Russian Space Agency in February of 1992. More significantly, it was the legislative branch of the new Russian government that gave the RSA its official charter; no longer would space efforts serve merely as an adjunct to military planning and capabilities. Under the old regime of the Soviet Union, no single agency was responsible for formulating, coordinating, and implementing all aspects of government space policy.[39] The mission of the RSA was to "make effective use of Russia's space rocket complex in the interests of the Russian Federation's socio-economic development, security, and international cooperation."[40] It was legislated as a separate, stand-alone line item in the government's budget and its organizational structure is highly suggestive of

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[39]Office of Technology Assessment, 31.

[40]Russian Federation President. *Decree Establishing the Russian Space Agency*, Moscow, February 1992. Boris Yeltsin.

NASA's organization. The RSA represents a dramatic break from its Soviet heritage in several important regards.

Under the reorganization of the Russian space program, the civil and military spheres of responsibilities are clearly delineated. Even though the military still warrants the lion's share of financial resources, military personnel are gradually being winnowed away from all launch and operations facilities. Civilian personnel will be eased-in as military personnel are eased-out. Ultimately, civilian personnel will be responsible for the maintenance and operation of all commercial satellites, providing support to the Space Station Mir, and for also providing support and launch services for the ISS. An obvious priority of the Russian Federation has been to eliminate the military hegemony of its space activities. From budget allocation to personnel manning, Russian civilians are increasingly more and more visible within the RSA.

2. Western-Supported Technology Transfer

The new charter of the RSA has also allowed for ready access of launch service technology by interested Western parties (both governmental and private interests). Because the military's role has been (and continues to be) de-emphasized and separated, the transfer of sensitive technology is easier to control. It is also far easier for elements of the civilian RSA to initiate cooperative ventures with NASA and the European Space Agency (ESA). The RSA has in fact become a clearinghouse for any organization desiring to do business with Russia in any commercial space endeavor.[41]

Before it can stabilize and grow through consolidation, the RSA must carefully assess the current economic environment. Funding for space programs declined dramatically in the six-year period ending 1995. Over this same time period - and relative to GNP - the space budget contracted to 0.29 percent from an estimated 0.73 percent, or from $3.9 billion to $.69 billion, considered in pre-reform rubles.[42] RSA must also address concurrent drawdowns in other aspects of its space mission. R&D programs have fallen off by more than two thirds (197 R&D programs to 76), percent of spacecraft operating beyond warranty has increased from 30 percent to 59 percent, and new system development has skyrocketed from an average duration of 6-8 years to greater than 15.[43]

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[41]Ibid., 33.

[42]M. V. Tarasenko, *Current Status of the Russian Space Program,* Space Policy, Volume 12, Number 1, February 1996, 22.

3. RSA and the Impact of Privatization

RSA should be an effective stabilizer as more industries and enterprises of the Russian government are privatized. In the privatization of Russia's most prominent space enterprise, Energiya Scientific Production Organization, ownership of 38 percent of the company was maintained by RSA. RSA oversaw the disposition of the remaining 62 percent, including the 25 percent represented by privatization vouchers. As Russian aerospace companies become more financially secure and established within the international commercial market, the extent to which RSA has to continue to subsidize the supporting infrastructure will decrease. In the interim, RSA will act as the only filter and stabilizer as Russian Space entities shed government ownership and become privatized.[44] With the RSA now having authority over technology proliferation as well, it has additional leverage to control the privatization process. Having achieved equilibrium of sorts in privatization, RSA must turn its attention to other troubled aspects of its own space industries.

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[43]Ibid.

4. Russian Federation Financial Delinquency

Difficulties confront the RSA along all fronts of production and many of these difficulties are directly attributable to non-payment of bills to contractors and sub-contractors by the RF government. A prime contractor has to account for delayed payments from RSA for its Soyuz launchers. This same contractor is in no hurry to pay its subcontractor(s). Financial duress and uncertainty permeate the contractor and subcontractor relationship network. Three dozen enterprises subordinate to RSA have a cumulative debt of 500 billion pre-reform rubles while the government owes them close to 470 billion pre-reform rubles (approximately $100 billion). Salaries in the space industry are nearly 25 percent lower than those in non-defense industries. Actual payments of salaries are often delayed as well. As one might expect, there is a significant loss of personnel and expertise in the space industry. By the end of 1994, employment in the space sector had declined to 65 percent of its 1989 level. In fact, many of the "employed" merely use the space job as an anchor while they pursue more profitable business

[44] Office of Technology Assessment, 33.

opportunities elsewhere.[45] These problems are not trivial, but there is a very real sense that the worst may be over.

5. Causes for Optimism

The new management structure of the Russian space program as represented by the RSA offers several reasons for optimism. The RSA continues to successfully distance itself away from military control and military concerns. It has its own charter, sanctioned by a legislative body, the Russian Duma, and it is solely responsible for all aspects of Russian space policy. It is serving as a ready and able conduit for Western commercial space interests and has been highly effective in initiating cooperative ventures with NASA and the ESA. Because it is now in control of all aspects of space system development, it can take advantage of previously unrealized economies of scale. As the lead agent in privatizing space enterprises, it can best manage each space company's transition to a market economy. It is indeed well positioned to nurture and manage the continued growth of the Russian space program. As RSA shores up the remains of the Soviet space program it will increasingly reach out to the world space market and Russian commercial space interests.

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[45] Tarasenko, 22.

As the RSA consolidated its position as preeminent among space organizations of the former CIS it had to confront significant challenges. While adjusting to dramatically reduced state contracts, hyperinflation, and essentially a complete breakdown in traditional supplier and customer networks, RSA was left wanting when it came time to gain Western technical and financial support for its space endeavors. In fact, many elements of the RSA felt that further contacts with Western commercial interests were fruitless unless hard currency was provided upfront. Because the RSA was often reluctant to provide detailed financial and technical information for the would-be investors, no investment occurred.[46] Hard currency was not to be realized in the Russian market either. On the heels of the dissolution of the USSR, there was a gradual realization that there had been no accumulation of capital by any sector of the economy. Now, however, Russian banks figure prominently into the financial viability of the RSA commercial space efforts.

The basic mechanisms of a market economy are quickly emerging in Russia. Russia now has about 2,500 licensed commercial banks (of which some 500 are allegedly owned by the mafia, or have prominent mafia-ties), 600 investment

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[46]Office of Technology Assessment, 57.

funds and 40 million shareholders.[47] Privatization has proceeded rapidly as well. Over 15,000 medium and large enterprises have been offered to shareholders. Proportionately, Russia's state-owned sector is less than Italy's.[48] Because Russians save as much as 33 percent of GDP, Russian banks now have significant capital reserves available for market entrepreneurs and risk-takers. Capital accumulation has slowly developed and the RSA must work with the banks in tapping this financial resource.

The RSA is compelled to look outward, to the market for capitalization and marketing of its cooperative space ventures. Unlike the US space program which accounts for roughly 0.5 percent of GNP (around $30 billion), the Russian Federation space program is suffering personnel downsizing, technology proliferation issues, and a significant exodus of experienced personnel (including engineers) out of its space industries.[49] Additionally, because the space design bureaus once predominantly specialized in specific equipment, with a narrow range of possible applications, they have been slow to adapt to an open field of competitive opportunities. The RSA is in dire need of some old-

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[47] The Economist, *A Silent Revolution* (Essay), April 8 1995, 1.

[48] Ibid.

fashioned venture capital firms to get its initiatives off the ground.

C. CONCLUSION

Since the demise of the Soviet Union and the old Soviet space program, the RF government undertook significant actions to stabilize the precarious state of its space industry and those of the members of the CIS. Although this process is by no means complete, and the final stabilization of the RSA and RF space industries remains problematic, the trendline is positive. There are indeed reasons to be optimistic about the projected end state of the RSA and RF space capabilities within the management structure of the ISS.

As the RSA increases its international commercial activity, there are opportunities for profitable interaction with private interests. Bear in mind that it was only in 1992 that a consortium of Russian space enterprises, Informcosmo, signed its first contract with the US Company Rimsat for the production of Gorizont communications satellites. These satellites were successfully launched two years later and serve customers in India, Malaysia, and

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[49]Grigori S, Khozin, *Russian Space Commercialization - getting the banks involved*, Space Policy 1996, Volume 12, Number 3, 157.

Taiwan.[50] Russian banks have yet to fully prove their viability in financing space activities, but they are nevertheless important strategic partners for RSA in carrying its space initiatives forward.

Concerns about proliferation of Russian ballistic missile technology are serious enough to offset the risks posed by a partnership with the Russians in the ISS.

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[50]Committee on Science, Space, and Technology, page 133.

IV. RUSSIAN FEDERATION SPACE CAPABILITIES

A. CONCEPTUALIZING THE RUSSIAN SPACE PROGRAM

1. A Typical Space Architecture

Before beginning the analysis of the current RSA space program, a proper sense of the functionality of a typical space mission architecture should be presented and discussed. Analyzing the role and capabilities of the RSA within this architecture will then be a more natural process; and it will be subsequently easier to analyze and understand the strengths and weaknesses of the RSA.

The mission concept, that is, the overall goal of the space system, defines the entire scope of the space mission architecture. Typical examples of a mission concept are global cellular communications, imagery satellites, weather satellites, network television satellites, etc. There are seven sub-components[51] of a space mission architecture:

(1) Subject.

(2) Space Segment (Payload and Spacecraft Bus).

(3) Orbit and Constellation.

(4) Launch Segment.

(5) Command, Control, and Communications Architecture.

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[51]Larson, Wiley J. and Wertz, James R. editors, *Space Mission Analysis and Design* (Torrance, California: John Wiley & Sons, Inc, 1995), 9-11.

(6) Ground Segment.

(7) Mission Operations.

The RSA has inherent strengths and commercial and scientific applicability in some of these sub component areas, weaknesses in others, and little or no commercial applicability in the rest. What elements make up these sub-component areas?

The subject of the mission answers the question: "What information will the satellite provide that achieves our goal, what function will the satellite perform?"[52] It could be terrain by a geo-mapping satellite, temperature and pressure by a weather satellite, a rocket plume by a missile detection satellite, etc. Depending on the answer to this question, the RSA may or may not have a significant role in the subject definition. (This is certainly the case in the realm of satellite communications where the subject is almost always defined by commercial consortiums like Bill Gates' Teledesic and Motorola's Iridium.) The payload is another sub-component largely determined by the primary user of the space system. The payload portion of the space segment represents the aggregate hardware and software

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[52]Ibid. In fact, all sub-component definitions in this section are derived from Wiley and Larson. The "SMAD" is an essential tool in comprehending the overall methodology and physics involved in translating an idea or goal into a viable space system. It is a superb reference tool and highly informative.

systems that sense or interact with the subject. On an international or joint commercial venture, the RSA will often have little or no impact in this design area. The last sub-component area where the RSA will have little or no impact is in the orbit constellation design. Constellation design is a direct function of the subject and payload capabilities. If the designers want to target only one specific part of the globe, all the time, then a geo stationary satellite is preferred. If the goal is to get wide area coverage, with long dwell time, then a highly elliptical orbit is preferred. There is little or no likelihood that the RSA would be a significant factor in subject definition, payload architecture and constellation. The commercial market will largely determine the design and innovation in these sub-component areas. Because of its historic emphasis on military applications, these commercial sub-component areas are not the RSA's strongest selling points.

2. Russian Strengths within the Space Architecture

The launch segment is the most readily identifiable "space system" of any space architecture. It includes the launch facility, launch vehicle, and any upper stage vehicle required to place the satellite or spacecraft system in a particular orbit. The launch segment also includes associated ground support equipment and facilities. The RSA launch segment has two very successful elements, the very reliable Proton rocket and the robust launch facilities at the Baikonur Cosmodrome in Tyuratam, Kazakhstan. These two elements are proving to be among the most common variables in international space ventures and they also figure prominently in plans for the ISS. The facilities at Baikonur and the Proton launch vehicle will be examined in detail in the next two sections.

The Command, Control, and Communications (C3) architecture is the arrangement of components which satisfy the mission's C3 requirements. It requires specifications on data rate delivery and the nature of the system interface with space and ground assets. Because of the extensive nature of the old Soviet space program, the RSA has a wealth of C3 experience and existing communications infrastructure that can be readily tapped into for new space systems. There is a minimal learning curve involved with the RSA in C3 architecture design and application. Similarly, the ground segment, which commands and tracks the spacecraft, is well defined within the RSA program. If these assets are managed properly, the US and other coalition partners, as well as commercial entities, can realize significant economies of scale by judiciously utilizing pre-existing RSA facilities and communications networks. Finally, mission operations consist of the people occupying the ground and space segments, the mission operations concept, procedures, and data flow. Because the C3 architecture is a significant part of mission operations, the RSA may have a significant role in this sub-component area as well.

The methodology for identifying, assessing, and integrating the RSA distinct technological, managerial, and operational advantages will be developed in the areas the US and ISS are most likely to draw upon for their space initiatives: the launch facilities at Baikonur and the Proton rocket launch vehicle. For the RSA and the ISS to truly be successful and conduct sustained commercial and scientific endeavors in the 21^{st} century the inherent capabilities and advantages of the Baikonur launch facilities and the Proton launch vehicle must be fully understood and fully leveraged. The key for the US space program and other users will be how to determine the nature of a successful relationship with the RSA, the advantages in doing so, and the identification of any possible hazards in working with the RSA.

B. BAIKONUR LAUNCH FACILITY

1. Location and Early History

The Baikonur Cosmodrome is the world's oldest space launch facility, ground having first been broken on 1 May 1955. The name "Baikonur" is actually a misnomer. Baikonur is a small mining town located some 370 km northeast of the facility. The actual Cosmodrome is located in Tyuratam, near present day Leninsk (see Figure 2). The deception was

Figure 2. Tyuratam (Baikonur), East of the Aral Sea.

intentional. The Soviets hoped to delay and confound the discovery of the launch facilities by US and NATO reconnaissance assets for as long as possible. Misnaming

and misplacing geographical locations was part of this deception.

The original concept of Baikonur called for a facility less susceptible to US surveillance and closer to the equator. Such a move to more southern latitudes enabled Soviet ballistic missile engineers to gain increased liftoff velocities for their rockets due to the increased velocity of the earth closer to the equator. This increased take-off velocity provided a 4 percent payload bonus compared to the other Soviet alternative of Kapustin Yar.[53] The initial scale of construction was extensive: in addition to the world's largest launch pad (45m deep by 250m long by 100m wide) for the R-7, the early Cosmodrome facility included an airport and hangar bay assembly. It has grown considerably since the launch of Sputnik I in October of 1957 and there is good reason why it is the crown jewel of the RSA space program.

2. Launch History and Capabilities

The Baikonur Cosmodrome is the world's oldest space launch facility and it has over 1,000 successful space launches to its credit. It routinely leads the world in the number of annual launches, having amassed over 40 for the

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[53]Harvey, page 19.

launch year ending 1996.[54] Baikonur can readily support such a robust optempo because of its size and capability to support a variety of launch vehicles. Covering a land mass of over 2,700 square miles, this facility consists of nine launching pads with 14 launching tables, 34 technical complexes, two airfields, a launch tracking center, three filling stations for spacecraft and the world's largest oxy-nitrogen plant. Figure 3 offers another perspective of the Baikonur Cosmodrome.

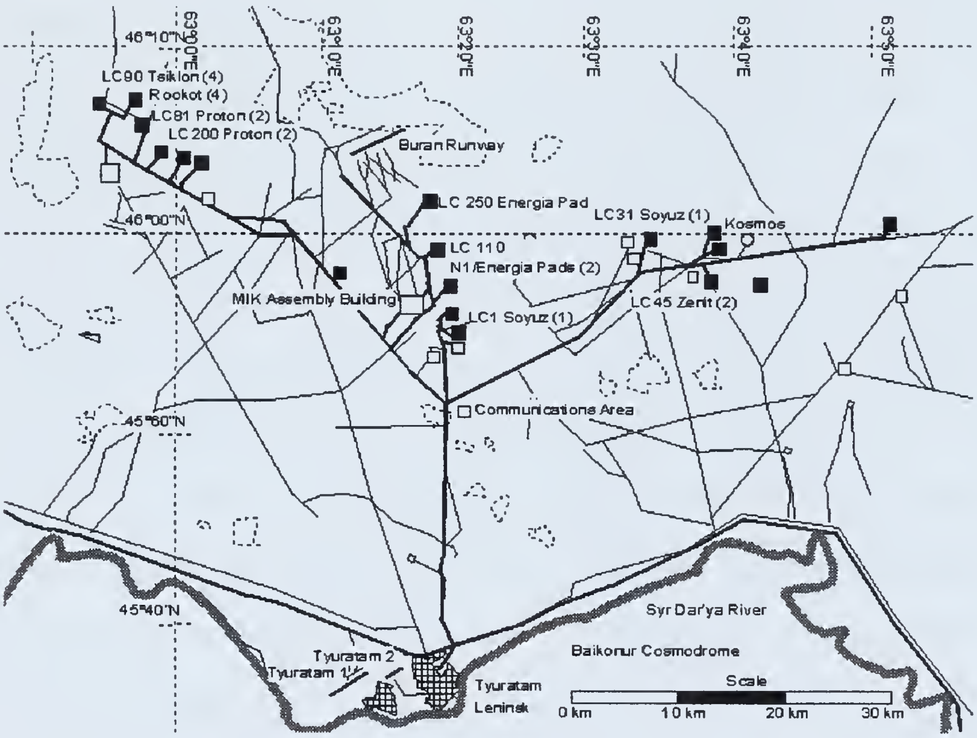

Figure 3. Map of the Baikonur Cosmodrome Facilities.

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[54]U.S. Congress. House. *Oversight Visit. Baikonur Cosmodrome.* House Report 103-451, Wasington D.C.: Government Printing Office 23 March 1994, page 17.

However, Baikonur also supports the Soyuz and Molniya series of launch vehicles as well as the Tsiklon and Energiya series.[55] A truly massive complex, it is an entire city dedicated to the single industry of launching rockets.

The extensive support facilities of the Baikonur Cosmodrome, its ability to support a variety of launch missions (supporting payloads from 2 tons to 88 tons) and its 40+ launches per year, 1000 launch experience have made it a dominant player in the international market for launch services. Baikonur will support all the heavy lift requirements of the ISS, and 30 percent of the total launches for the space station between 1998 and 2000. Commercial consortiums are also eager to use the facilities at Baikonur, with Motorola's Iridium system relying on Baikonur to launch 21 of its 66-satellite network. On 7 April 1998, Proton successfully completed its last launch of Motorola's Iridium satellites. The Proton placed almost one third of the constellation, 21 satellites altogether, in orbit for Iridium.[56]

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[55]Office of Technology Assessment, 37.

[56]AP Wire Services, *Iridium Launch From Russia Successful,* April 7th, 1998.

Baikonur covers a greater land area than the city of Chicago. It represents a 40+ year effort to support all aspects of a space launch. When viewed from another perspective, the sheer versatility and massive complexity of the Cosmodrome facility awes its visitors as well as its full time residents. Figure 4 offers another perspective of the capabilities and extensiveness of the Baikonur Cosmodrome. The numerous facilities highlight its multiple mission capability and extensive infrastructure.

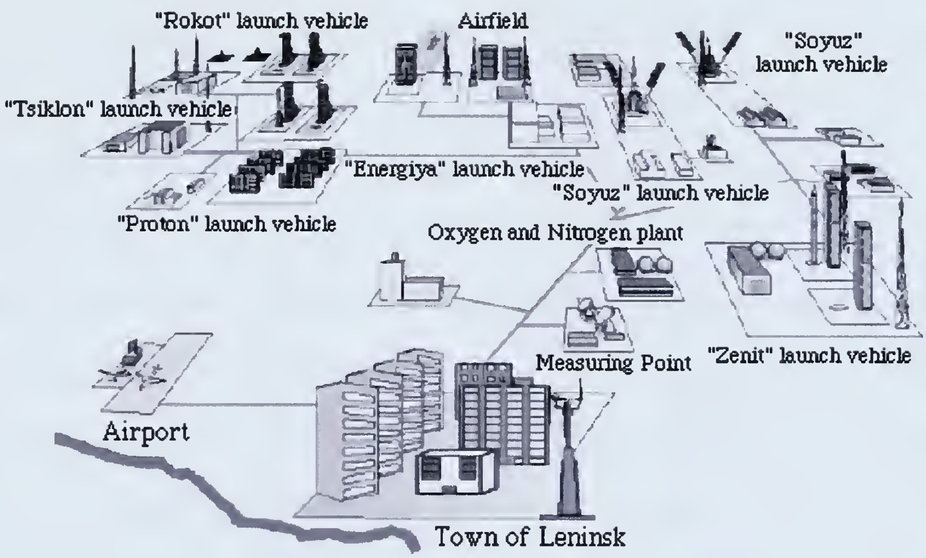

Figure 4. Baikonur Cosmodrome - another perspective.

For the RSA, the Baikonur Cosmodrome is starting point for all man and man related lunar, interplanetary, high-

altitude, and geo-synchronous missions.[57] Despite, or perhaps because of, the prominent role of this facility in the Soviet space program, Baikonur's role in international launch services since the fall of the Soviet Union has been anything but certain.

3. Impact of the dissolution of the Soviet Union

The break up of the Soviet Union jeopardized the complex infrastructure of the Baikonur facilities and, in fact, Baikonur is a case in point for concerns about the RSA's decaying space infrastructure. Because of the dispute between government officials of Kazakhstan and Russia, Baikonur's already utilitarian facilities rapidly deteriorated. There have been news reports that the infrastructure is indeed deteriorating and that many facilities and work centers lack central heat, electricity, running water, and are in severe disrepair.[58] These conditions and lack of pay have exacerbated an already discontented work-force at Baikonur. There have also been strikes and protests about the working and living conditions at the facilities and in the neighboring town of Leninsk, where many workers live. There have even been reports of

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[57]Federation of American Scientists, *Space Launch Vehicles*, [http://www.fas.org/spp/guide/russia/launch].

[58]Michael Specter, "Where Sputnik Once Roared into History, Hard Times take Hold," *The New York Times*, 21 March 1995, section C1.

thieves using camels to pull copper cable out of the ground and selling it for its value as a raw material. One launch at Baikonur was reportedly cancelled due to the theft of specialized support equipment.[59] Officials are also grappling with larger social issues that effect the readiness posture of Baikonur.

During the wrangling between the two governments, neither government controlled the administration of the city. Thousands of nomadic Kazakhs subsequently entered the city and now occupy former dwellings left vacant by the departed Soviet Space Forces. In a city once dominated by Russians, Kazakhs now make up over 50 percent of the population.[60] Although these reports are more symptomatic of the state of the space program upon the dissolution of the Soviet Union rather than a reflection of Baikonur in 1998, there are legitimate concerns that the RSA will not be able to respond to the challenges of modernizing the Baikonur facilities.

4. Causes for Optimism

The first step to the restoration of Baikonur was resolving the relationship between the Russian Federation

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[59]Vladimir Ardayev, "Kazakhstan: Depressing Landscape With Fireworks," *Isvetiya* (Moscow), 3 November 1994, page 4. (Foreign Broadcast Information Service translated text.)

and Kazakhstan. On 28 March 1994 Russia agreed to lease the Baikonur Cosmodrome from the government of Kazakhstan for twenty years at a price of approximately (US$) 115 million per year.[61] Russia's government and the RSA immediately began to bolster the facilities' infrastructure and commercial prospects. In an attempt to facilitate the transition to commercial enterprises, the Russian military presence is being gradually reduced while the civilian staff is being increased. The Russian government of Boris Yeltsin has also pledged financial and material support to the city of Leninsk as well as allocating sufficient funds to construct new housing for the 16,000 military troops who support Baikonur. Emphasis has been placed on utilizing, maintaining, upgrading, and retooling the space facilities at Baikonur.[62] Commercial investment quickly followed on the heels of government investment.

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[60] Peter De Selding, "Baikonur Undergoing Profound Transition," *Space News*, 11 September 1995, page 4.

[61] Office of Technology Assessment, 36.

[62] Russian Federation President. Russian Presidential Edict No 2005 (Boris Yeltsin) and Russian Federation Government (Duma) Decree 996 of 24 October 1994 and 29 August 1994, respectively. These two documents commit the President and RF government to ensuring the viability of all aspects of the Baikonur facilities. They both address quality of life issues for servicemen of the Military Space Forces, as well as addressing operational expenditures, purchases of series-produced space equipment, capital construction and upkeep for the city of Leninsk. The RSA and RF are clearly leaving nothing to chance in an effort to ensure the long term viability of Baikonur.

Lockheed Aerospace is building a satellite processing facility and a second Proton launch pad at Baikonur at an estimated price of $100 million. The two projects will be completed this year and they will significantly increase the viability of Baikonur in the commercial launch industry. Indeed, with the successful launch of its Iridium payload for Motorola, more and more commercial endeavors are focusing on the capabilities of the Baikonur launch facilities.

C. PROTON LAUNCH VEHICLE

1. Launch History and Capabilities

The Proton is the largest launch vehicle in the RSA inventory and it currently has the heaviest payload capability offered on the commercial market.[63] The Proton is used in the three stage variant to place payloads in low earth orbits and in the four stage configuration to launch heavier spacecraft into higher orbits.[64] The Proton has the most launches in space history to its credit (238).[65] It

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[63]The Buran Energiya (Angara 5) will have a Geosynchronous payload of twice that of the Proton (roughly 5 tons to 2.5 tons). However its operational effectiveness has not been tested in actual orbit and its commercial viability is far from certain.

[64]Eric F. Laursen and John E. Voce, *The Proton Launch Vehicle System Current Status*, 16th International Communications Satellite System Conference, February 1996, page 2.

[65]M. V. Sinelshchikov, "Russian Launch Vehicles' State of the Art and Lines of their Improvement, ESA pub, SP-362, March 1994, 7.

has been in production since the mid 1960's, and its current variant, K, is quickly being recognized as the most reliable, cost effective launch vehicle offered on the commercial market.

The Proton is the world's pre-eminent space launch vehicle. No other launch vehicle has the ability to place payloads of such varying weight into so many different orbits. It can place a 23 ton payload in a low earth orbit, an 8 ton payload in a geosynchronous transfer orbit, and with its Breeze M engine update, it will be able to place an unrivaled 4 ton payload into a geosynchronous orbit.[66] It can do so far more economically than its closest competitors. Its average price per launch is $50 to $70 million. Shuttle launches cost anywhere from $160 to $215 million. The Titan IV costs from $240 to $270 million. The space industry measurement of costs is best determined by the price per pound that it takes to place a given payload in orbit. The Proton only costs $2,000 per pound. In comparison, the shuttle costs about $12,000 per pound. The

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[66] [WWW.dot.gov/faa]. Characteristics of Launch Vehicles. This is a limited, but effective web site for assessing launch vehicle comparisons.

Titan IV and Ariane V are 50percent more expensive than the Proton on a per pound basis.[67] With its 5 year reliability of 96 percent[68], and the overwhelming cost advantage, the Proton is without peer in the international launch service arena and it is shown below in Figure 5.

Figure 5. Proton D being placed into its vertical launch position at Baikonur operations pad.

An agreement between the RF and US governments allows only limited use of the Proton for commercial applications

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[67] [WWW.rocketplane.com]. The Competition. This is another website that offers a fairly current comparison of the major launch vehilces.

[68] Lausen and Voce, page 2.

through the year 2000, and only if these services are offered at not less than 7.5 percent below international market value. Iridium missions are also permitted under this agreement.[69] Table 1 below compares the relevant aspects of the world's primary launch vehicles.

Launch Vehicle	LEO Payload (pounds)	GEO Payload (pounds)	Price (Millions)	Price per pound	Reli-ability (percen t)
Proton	46,297	4,850	$50-70	$2,000	96[70]
Shuttle	40,000	5,203	$500	$12,500	98.1
Titan IV	39,100	10,200	$240-270	$4,570	87.0
Atlas IIA	16,050	3,307	$65-80	$5,300	100
Delta II	11,109	N/A	$58	$5,800	94.8
Ariane V	39,600	N/A	$114-143	$4,924	50.0
Long March IIE	19,400	3,300	$40-50	$3,000	87.8

Table 1. Launch Vehicle Comparisons.[71] Green indicates first or second place in a given category, red indicates last place in a given category. Proton has the best overall mix of positive indicators.

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[69] *Fact Sheet. US-Russian Commercial Space Launch Agreement*, The White House, Office of the Vice President, September 2nd, 1993.

[70] Laursen and Voce, page 1.

[71] This table was compiled primarily from three diffent websites: [www.rocketplane.com], [www.dot.gov], and [www.bhm.tis.net]. Where data conflicted or appeared inconsistent, the most recent and/or precise source is used.

2. Proton's Strengths

Several conclusions can be quickly reached by examining Table 1. The Proton launch vehicle offers the greatest payload range and it can place more payload weight - more than 23 tons - into a LEO. Only the shuttle and the Titan IV can place more weight in a geosynchronous orbit (GEO), but at a price of 3 to 10 times more. The Proton offers a savings realization of over $400 million dollars over the shuttle for GEO orbits. With the Breeze M modification to the Proton's engines, the cost per pound of payload will be halved to $1,000.[72] Overall, the Proton offers the greatest payload flexibility at the least expensive price, with the greatest degree of reliability. It is no surprise that the ISS Freedom will rely on the Proton for all its heavy lift requirements.

If the US and the ISS Alpha, as well as commercial space organizations, are to successfully rely on the Baikonur Cosmodrome and the Proton launch vehicle, there must be a clear methodology to determine insightful and comprehensive measures of effectiveness (MOE) of the RSA operational, technical, and managerial impact on these

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[72] [www.Imco.com/ILS]. International Launch Services is the joint Lockheed Martin-Krunichev-Energiya (LKE) consortium that markets the Atlas and Proton launch vehicles for commercial launch services.

systems. These MOE must be able to readily track and assess the strengths, weaknesses, overall viability, and to possibly identify areas of vulnerability, for Baikonur and the Proton. This is an emerging challenge, to be sure.

The percentage of global launches represented by Baikonur, and the annual value of billed services are the clearest indicators of overall managerial and operational viability for Baikonur. Last year, Baikonur was responsible for over 42 percent of international commercial launches. Similarly, the reliability of the Proton and the cost per unit weight of payload are the most important MOE in predicting the long-term viability of this launch vehicle. No other launch vehicle offers the reliability, affordability, and payload flexibility of the Proton. Beyond the flexibility afforded by launches from Baikonur, and the economical reliability inherent in the Proton launch vehicle are there additional technical and scientific advantages to working with the Russians?

D. IN SITU BILOGICAL EXPERIENCE AND INSIGHTS

1. Extended Space Presence

Forty years of Soviet emphasis on long duration human exposure to the space environment has resulted in the Russian space agency being pre-eminent in in-situ data and research of the space environment. They possess unrivalled insight on how to best integrate the physical and psychological demands of space into mission operations.[73] The U.S. has been trying to gain this same insight by also having its own astronauts experience extended stays onboard the Space Station Mir.

2. Microgravity Experience

The Russians also have extensive experience in working in microgravity environments, which offers extensive opportunities for ISS scientists and engineers. The ISS will also seek to benefit from this experience. Its Gravitational Biology and Ecology Program will examine the role and effect of gravity on the evolution, development and function of certain biological processes.[74] Areas where the Russians may offer the best insight and experience include, but are not limited to, cellular and molecular biology, and the gravitational effects on ecological systems. The Soviets extensive, multi-decade track record with extended space stays extends beyond the realms of biology and ecology.

One of the goals of the ISS' microgravity experiments will be to gain an understanding of how buoyancy-driven

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[73]For the ISS emphasis on life sciences and effects of long term space exposure, refer to the ISS website [http://station.nasa.gov/science/disciplines/life/index.html].

[74]Ibid.

convection and sedimentation affect the processing and manufacturing of materials.[75] In the microgravity environment of space, acoustic and electromagnetic forces have greater influence than other processing techniques. The end result could very well be improved optical fibers for telecommunications and optoelectronics, as well as possibly helping the development of bioceramic artificial bones.[76]

Russian in-situ expertise with microgravity applies to other scientific disciplines as well. The fluid physics of multiphase fluid flow and solid-fluid interface can lead to breakthroughs in the design of earthquake-proof buildings and improved performance of power facilities. Microgravity experiments in combustion efficiency technologies will ideally lead to reduced combustion pollution and better fire control and suppression technologies.[77]

The Soviet Union's and Russian Federation's 40 year track record for extended human presence in space offers a wealth of in-situ data and experience in the areas of microgravity and space effects on human physiology. Key

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[75]Refer to another page at the ISS website. It pertains to microgravity sciences at: http://station.nasa.gov/science/disciplines/microgravity/index.html.

[76]Ibid.

[77]Ibid.

scientific endeavors onboard the ISS will be based on, as well as build on, Russian expertise. Soviet and now Russian experience in these areas will, and should be, exploited to minimize the learning curve for future scientific advances in bio-medical technology, fluid physics, manufacturing processes and pollution control. The ISS offers an ideal opportunity to benefit from historical scientific strengths of the Soviet, and now Russian, space program.

E. CURRENT COMMERCIAL RELATIONSHIPS

1. Lockheed Martin, Boeing, et al.

There are several prominent commercial space firms and space-related industries in the U.S. currently enjoying and profiting from the distinct technical and scientific advantages offered by the Russian space industry. Lockheed Martin Aerospace is among the US leaders working with the Russians and has formed a cooperative venture through LKE International (Lockheed-Khrunichev-Energia). It jointly markets the Atlas and Proton under the consortium International Launch Services (ILS). Boeing is also attempting to develop prospects involving Ukrainian launch vehicles and a variety of converted Russian missiles.[78] Motorola launched five of its Iridium satellites aboard a

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[78]Office of Technology Assessment, 58.

Proton rocket and is leading the international market in acquiring Russian space services. Launching five satellites on one launch vehicle saved Motorola over $10 million. These successes have expanded marketing opportunities for the RSA in the US.

2. Engine Technology

Russian launch vehicles and propulsion technology have been introduced to the US through purchase and co-production agreements. Aerojet and Pratt & Whitney have each announced activities designed to replace the engines of existing US launch vehicles. At the Gore-Chernomyrdin Commission meeting in June 1994, Pratt & Whitney also announced that it would be working with NASA in exploring the possible application of tri-propellant-rocket-engine technology developed by NPO Energomash.[79] The successful alliances extend beyond the realm of hardware and launch services.

Russian remote sensing data products and services have been successfully marketed in the US. Firms including EOSAT, Worldmap International, and Core Technologies have announced the availability of Russian optical imagery with spatial resolution as good as two meters, as well as radar data from the Almaz satellites. There have also been efforts to apply

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[79]Ibid, 58.

Russian materials science expertise as well as other technologies to US aerospace products. Kaiser Aerospace and Electronics and McDonnell Douglas are among the firms pursuing these possibilities. The RSA offers extensive in situ experience, resources and scientific data in fields and specialties where US experience is limited, if not nonexistent. McDonnell Douglas has established joint research centers in Moscow and Huntington Beach, California, with the Mechanical Engineering Research Institute of the Russian Academy of Sciences. McDonnell Douglas is also pursuing technology and software development efforts.[80]

Despite the fact that the legal framework and business culture in Russia are still maturing, there are current agreements and business ventures in place that have been successful and profitable for both parties. What is the nature of these agreements and what elements within them have been the keys to success? Are there additional opportunities for expanded space cooperation between US agencies and firms and the RSA? Are there additional constraints and impediments to address?

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[80] Ibid, 58.

F. COOPERATION AND OPPORTUNITY

1. NASA Steps In

Cooperation between the US and Russia is not limited to governmental agreements. It includes inter-agency agreements between the RSA and NASA as well as private commercial ventures. The US government has clearly taken the lead. In 1993 the US administration of President Clinton initiated the merging of the US and Russian Space station programs with the management structure of the ISS. The political, commercial, and scientific ramifications of this merger will be felt for years, because the agreement will last at least until the year 2014.[81] Under this agreement the US will pay Russia $400 million for specific functions. NASA will directly pay the RSA. In fact, NASA Administrator David Goldin intimated that NASA would likely pay the RSA up to $100 million (above the earlier $400 million) a year for a total of ten years.[82] The financial incentive of this cooperation has its own purpose.

The $400+ million is related to the Administration's desire to use the national space policy as a supplement to

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[81] Committee on Science, Space, and Technology, 125.

[82] Ibid.

foreign policy regarding ballistic missile technology proliferation. This commitment should help preserve employment for Russian engineers and technicians in at least some of Russia's major space industrial centers.[83] The US insists that Russia end its plans to export its rocket engine technology to the Indian Space Research Organization. The initiative (and the $400+ million) worked; Russia has agreed to sell only rocket engines to India but not the underlying technology.[84] Russia and the US have also agreed to cooperate in space-based environmental observations and other aspects of space science. The Clinton Administration's National Space Transportation Policy directs the US government to negotiate and implement agreements controlling trade in commercial space launch services.[85]

G. CONCLUSION

1. Russian Strengths of the Baikonur Cosmodrome and the Proton

Within the accepted understanding of typical space mission architectures, Russia's capabilities in the launch

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[83] Space Policy, Volume 11, Number 3, August, 1995, page 210.

[84] Ibid. page 126.

[85] The White House. Office of Science and Technology Policy, "Fact Sheet-National Space Transportation Policy," 5 August 1994, 11.

segment are unparalleled. The extensive capabilities of the Baikonur Cosmodrome support a variety of launch vehicles in a variety of launch missions. Its 1000-launch history and ability to support as many as 40 launches per year make it, justifiably, the clear leader in providing international launch services. With nine launching pads and 14 launching tables, two airfields, its own dedicated railroad system, as well as the world's largest oxy-nitrogren plant, it offers more versatility at one location than any other launch facility in the world.

The primary workhorse of the Russian space segment is the Proton launch vehicle. With over 200 launches to its credit, its five year reliability rating of 96 percent is only surpassed by the U.S. space shuttle. No other platform offers the range of payload capabilities, from 46,000 pounds at a low earth orbit to 4,800 pounds at geosynchronous orbit, at the lowest price of $2,000 per pound. The Breeze M engine upgrade to the Proton will lower the payload cost to an astonishing $1,000 per pound. The reliability, versatility, and cost of the Proton launch vehicle make it the preferred launch service provider on the commercial market.

Motorola placed almost one third of its 66-satellite constellation Iridium into LEO from the Proton, launched from the Baikonur Cosmodrome. Boeing, Pratt & Whitney, and Lockheed Martin are also increasing the scope of their relationship with Russian space industries. American commercial aerospace and communication companies are clearly profiting from a commercial relationship with Russian space industry. The launch segment capabilities that these commercial companies enjoy will also well serve the International Space Station.

The ISS will also benefit from the extensive Soviet and Russian in situ experience in space duration and microgravity science. The Russians are sharing the biological and physiological experience gained from a long history of extended space duration on the human body. Their microgravity expertise will be a key enabler to developing innovations in the fields of fluid physics, pollution and combustion control, and processing and manufacturing.

2. Unlimited Potential

The potential to learn from and build on Russian space expertise is unlimited. The opportunity offered by the joint relationship of the International Space Station provides many positive possibilities for all participants, if the relationship, with all its risks and payoffs, are clearly understood. Understanding the exact nature and role of the Russian Space Agency in the ISS is necessary to protect the technological and commercial interests of the United States space industry.

V. RUSSIAN FEDERATION BALLISTIC MISSILE TECHNOLOGY PROLIFERATION AND THE INTERNATIONAL SPACE STATION

A. BALLISTIC MISSILE TECHNOLOGY PROLIFERATION AND THE RUSSIAN SPACE AGENCY

1. Russia and the Missile Technology Control Regime

The Soviet Union possessed a formidable ballistic missile capability to the very end of its existence. The questions and concerns about the consequences of the break up of the Soviet Union and its ballistic missile program were legitimate and troubling. With no centralized control of the space program and its supporting ballistic missile technology, what would happen to the personnel and scientific expertise embodied in the old Soviet space agencies and industries? The prospect of technical flight of these personnel and these technologies to other countries is as troubling a concern for national strategists today as is was seven years ago when the Soviet Union dissolved. In point of fact, the troubling fears of technical flight have been realized with a reduction in the Russian space-related workforce of 30-35 percent; some 200,000 personnel have left the space industry for jobs inside and outside the country.[86]

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[86]Office of Technology Assessment, 20.

Linking ballistic missile technology proliferation to financial support of the RSA and a partnership within the ISS is a challenging yet compelling proposition. Russia and the RSA should be given wide latitude, and fully supported, in their efforts to make meaningful contributions to the International Space Station. Partnership within the ISS may be the best, if not the only, avenue through which the US can consistently monitor the Russian commitment to, and progress in, ballistic missile technology proliferation control. From a larger perspective, Russia's ability to police itself, while also being policed, must be understood within the context of the Missile Technology Control Regime (MTCR) as well as its full fledged participation within the International Space Station.

The MTCR was originally established in 1987 with the aim of controlling exports of missiles capable of carrying nuclear weapons, as well as the required technology to do so. In 1993 controls were extended to include missiles capable of carrying biological and chemical weapons. The MTCR has 29 members. During the recent plenary meeting held in Tokyo, MTCR members reaffirmed that the MTCR continued to be an essential mechanism to prevent proliferation of missiles capable of delivering weapons of mass destruction.[87] In point of fact, it is a multilateral regime devoted to such a goal. The MTCR complements various global non-proliferation instruments including the Nuclear Non-Proliferation Treaty, the Biological and Toxin Weapons Convention, and the Chemical Weapons Convention.[88] The US updated its commitment to the MTCR on the 7th of January, 1993. In doing so, the US re-affirmed that it is accountable to the international community for open disclosure of ballistic missile technology proliferation.[89]

The MTCR represents a strictly voluntary and relatively informal agreement among several countries which share common proliferation concerns. The MTCR's main goal is to limit and control, if not eliminate, the proliferation of unmanned ballistic missile delivery systems for weapons of mass destruction (WMD).[90] It truly is an egalitarian arrangement: all partners have equal standing within the

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[87]Missile Technology Control Regime Plenary Meeting, Press Release. Tokyo, November 6th, 1997.

[88]Ibid.

[89]U.S. Government. State Department. U.S. State Department Guidelines on the MTCR. Washington, D.C.: Government Printing Office January 1993, 3.

[90][http://www.fas.org/asmp/campaigns/missiles/1997_plenary_info.html], *The Missile Technology Control Regime: An Information Paper.* This information paper was released by MTCR Member States following their 1997 Plenary Meeting in Tokyo. The http address is an American Federation of Scientists website. The page referenced here is a Q&A format that addresses, in lay vernacular, the most salient aspects of the MTCR.

regime and all MTCR decisions represent the consensus of signatories. The members of the MTCR also routinely provide pertinent export licensing issues to other members. It is essential to emphasize that the MTCR is the only multilateral arrangement that specifically addresses ballistic and cruise missile technology.[91] Russian participation in, and adherence to, the covenants of the MTCR are vital, given RF ballistic missile capabilities.

The MTCR dictates that greatest proliferation constraint be placed on complete rocket systems, to include ballistic missiles and space launch vehicles; this is the heart of Russian space capabilities. Also included on the MTCR control list are rocket engines, guidance systems, and warhead mechanisms. Production facilities are also included on this list.[92]

Russia's space and ballistic missile capabilities warrant the attention of the MTCR. This realization, and the desire to ensure another layer of proliferation compliance for the Russians, animated the agreement to reorganize the International Space Station Freedom to include a heavy reliance on Russia and the Russian Space Agency.

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[91]Ibid.

[92]Ibid.

2. The ISS as Proliferation Control Leverage

In the Fall of 1993 the U.S. government negotiated the re-organization of the International Space Station. Gone was the sole reliance on Western technology and infrastructure support. In its place was a re-worked Space Station, nominally referred to as "Alpha". ISS Alpha represents a systematic attempt to integrate the strengths of the Russian space program into the management and technology infrastructure of the pre-existing station. Within the new concept of the Space Station, the dual themes of national security policy and space policy were addressed. The reorganization was deliberately built upon the understanding that Russia will fully comply with the international standards concerning ballistic missile proliferation.[93] The motives are clear: the U.S. can best ensure the stabilization of the former Soviet aerospace industry by engaging it within the architecture of the International Space Station.

3. A Worthy and Strategic Goal

Cooperation with the Russians on the Space Station gives them, their space industries, and the Russian Space Agency a worthwhile goal upon which to focus their energies

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[93]John Pike, *Ralpha, Russian American Space Cooperation*, 10 December 1993, at [http://www.fas.org/spp/eprint/jp 931210.htm], *1*.

and talents. Their technical abilities will be harnessed to a sustained scientific endeavor and they will be able to both learn from and contribute to this undertaking. Given the exchange rate of the post-reform ruble, the U.S. commitment to Russian participation in the Space Station resembles a Marshall Plan of the cosmos.[94] A broad-based program of cooperation and engagement in the Space Station will act as a long term stabilizer to the Russian space industry. The most important aspect of the administration's efforts was to keep Russian scientists and engineers committed to positive endeavors and to prevent the possible transfer of personnel and missile technology to other countries.[95] Continued funding support for RSA will be directly tied to performance and management standards, and most significantly, technology proliferation compliance.

The new Space Station agreement confronts the reality of Russian ballistic missile technology proliferation: compliance with the MTCR is not as compelling as significant and sustained financial support. This is not a function as much of cynicism, as it is of realpolitik. Allowing and encouraging Russian participation in the re-organized International Space Station Alpha is the best insurance of

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[94]Ibid, 5.

controlling the ballistic missile technology of Russia and the RSA. It is important to recognize that this relationship is not strictly one-sided: the RF and RSA can offer significant technologic capabilities to the International Space Station.

B. THE INTERNATIONAL SPACE STATION AND THE RUSSIAN SPACE AGENCY

1. Revising the Space Station Design

The integration of the RSA and Russian space industries into the revised International Space Station Alpha was developed in detail as a result of the September 1993 U.S./Russian Joint Commission on Economic and Technological Cooperation, chaired by Vice-President Gore and RF Prime Minister Viktor Chernomyrdin. Russian participation was segmented into three distinct phases. The goal was to gradually incorporate the most conspicuous strengths of the space program of the former Soviet Union into the revised International Space Station.

Phase One established an exploratory association of the space programs of the United States and Russia. There were three distinct goals to Phase One. The first goal entailed a practical understanding of each country's design,

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[95] *Russian Involvement,* [http://station.nasa.gov/reference/status/russian1.html], 1.

development, training, and operational cultures. As the early anecdotes of the Soviet Space Program suggest, scientists in the U.S. and Russia might well approach the same engineering challenge in significantly different ways. The second goal of Phase One was to create and build an ever expanding corps of American astronauts and support personnel familiar with long-duration space flight. This is another specialty in which the Russians clearly excel. The third goal of Phase One was to reduce risk to the International Space Station Alpha by the demonstration of proven technology and testing concepts. In this regard, the long track record of the Proton launch vehicle and the sustained history of launch operations at the Baikonur Cosmodrome became design considerations which were integrated into the full scope of ISS operations. Phase One of the new ISS agreements was carefully built around, and tailored to, the strengths of the RSA. NASA and the RSA initiated a subset of goals to facilitate Phase One.

The NASA/RSA Protocol[96] aims to establish and nurture joint operational skills which are deemed to be critical transitional skills for both cosmonauts and astronauts. Two cosmonauts will fly on the shuttle and there will be a total

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[96] *Russian Involvement*, [http://station.nasa.gov/reference/status/russian3.html], 1

U.S. presence on the Mir of at least two years. There will as many as ten Shuttle and Mir docking missions which will serve as valuable experience for future Shuttle/Space Station dockings. There will also be a joint science mission and joint development of supporting technologies. The successful achievement of Phase One goals will ensure the smooth transition to the second and third phases.

2. Russian Contributions to the ISS

The second and third phases of Russian support to the ISS involve the actual construction and orbiting of ISS elements, like the FGB shown below in Figure 6. The Russians are responsible for designing and launching two of the first three elements of the ISS.

Figure 6. The Boeing-contracted, Khrunichev Productions Space Center-built, Functional Cargo Block (FGB). The FGB will be placed into orbit by a Proton launched vehicle from the Baikonur Cosmodrome.

The successful launching of these two elements will determine whether the ISS will be a viable space station, and whether the RSA and the Russian space industry prove to be worthy and legitimate partners. It is necessary to examine the scope and commitment of the RSA to the ISS, as embodied in the FGB and Service Module.

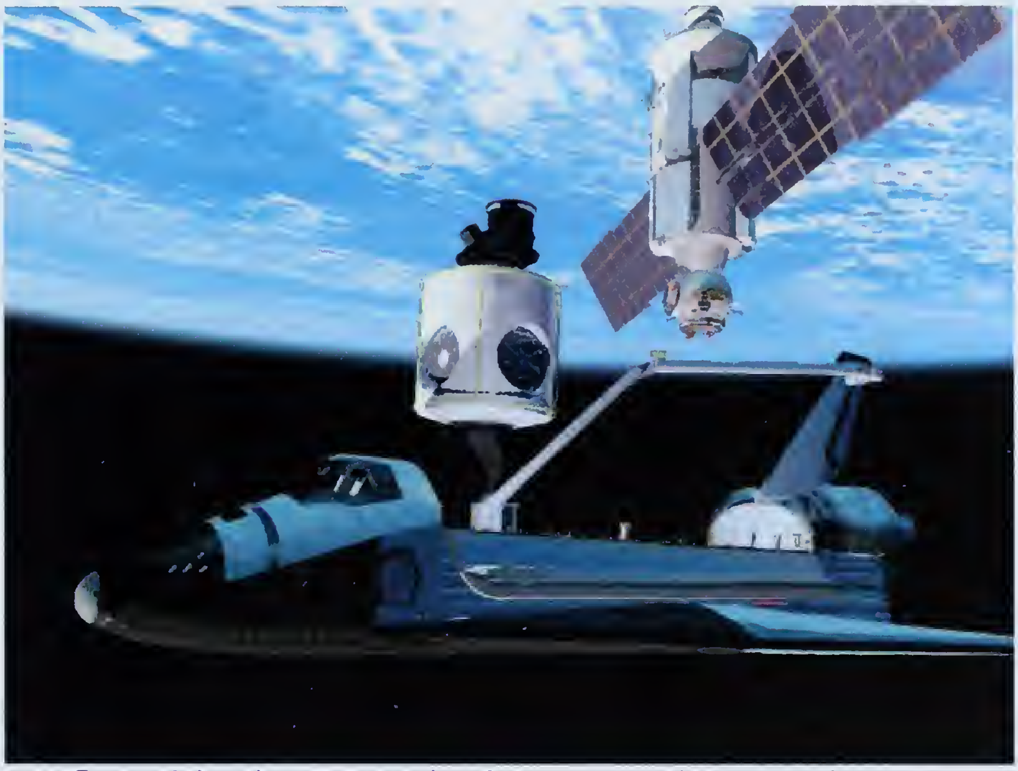

Figure 7. This is an artist's conception of the U.S.-built Node 1 adapter being deployed by the Space Shuttle. It is in its docking position with the previously-orbited FGB.

The FGB will be the first element of the ISS to be launched (see Figure 7). As the first element of the ISS, it will provide the initial propulsion and power to the space station. As construction and assembly of the space

station progress, the FGB will provide orbital control and communications power for the U.S.-built Node 1.[97] In the later stages of the ISS, the FGB will provide supplemental propulsion storage in its external storage tanks. This 20 ton, 41 foot-wide spacecraft will remain in orbit while it awaits to be mated with the Node 1 element as shown in Figure 8.

Figure 8. Another perspective of the Node 1 and the FGB, once the two elements have been coupled.

In an effort to increase the versatility and capability of the original Russian design, the Boeing Company was selected by NASA to act as the prime contractor. Boeing

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[97] *Functional Cargo Block,*[http://207.86.88.39/station/elements/fgb], 1.

emphasized versatility and upgraded electronics. As a result, the FGB now has a more robust attitude control function, increased orbital refueling flexibility with a docking port at its nadir, and upgraded avionics.[98] The FGB's refueling nadir (earth-pointing) port will allow the FGB to be refueled from the Russian logistics re-supply spacecraft Progress. This will lessen the fuel criticality of the Service Module (SM) and will result in a more versatile platform. Because the SM is the first element of the ISS to be launched, and because its functions of attitude control, power, and communications support for the Node 1 are absolutely critical, the success of the Russian-built FGB will determine the initial success of the ISS Alpha. The key to the long term success of the space station will be the successful design and orbiting of the Service Module.

The Service Module is truly the first all-Russian segment[99] designed and built exclusively for the ISS; there is no prime contractor in the US. The Service Module will serve as the initial living quarters for ISS personnel. The

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[98]*Modifications to the FGB Block,* [http://207.86.88.39/station/elements/fgb/mods.html], 1.

[99]*Modifications to the FGB Block,* [http://207.86.88.39/station/elements/sm], 1.

SM will provide the necessary life support systems, power and communications systems, as well as have a capability for ground-controlled remote command capabilities. The Service Module is massive at 21 tons and it will also be launched into space from Baikonur aboard a Proton. Figure 9 below shows a cutaway perspective of the Service Module.

The Service Module is derived from and similar in design to the Mir Space Station Core Module illustrated below.

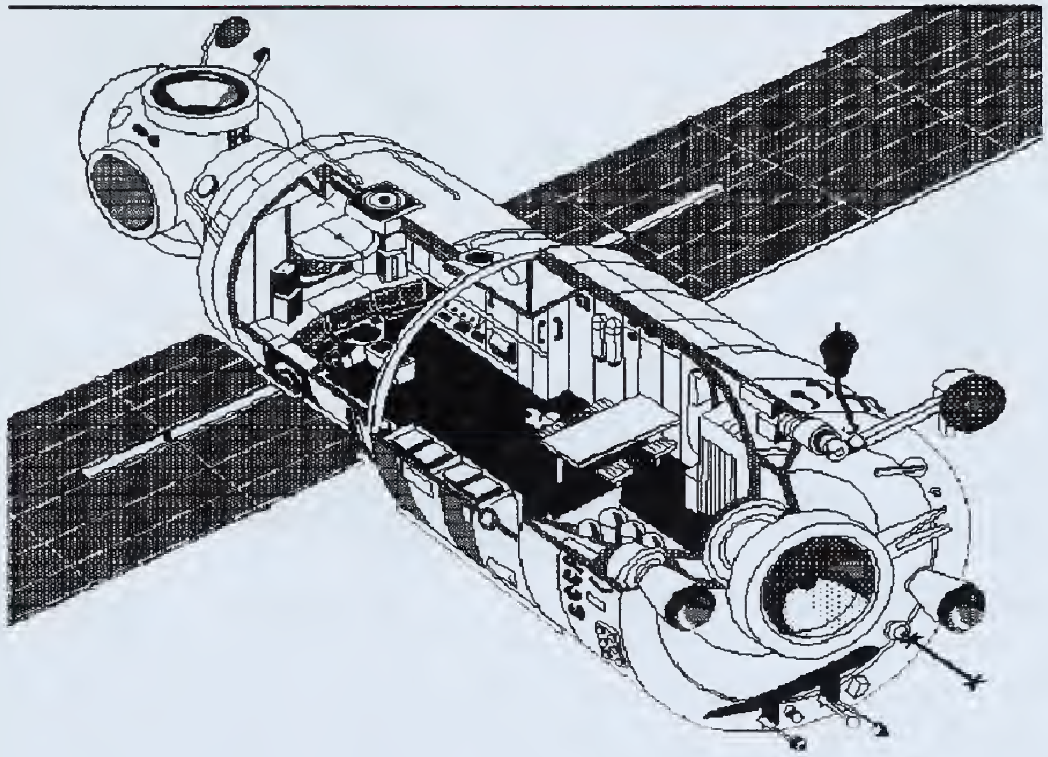

Figure 9. Cutaway view of the Service Module and its living quarters.

In a typical (Soviet and now) Russian engineering decision, the Service Module is mostly based on very proven

design technology. Although this may not sound like an endorsement, the Service Module design is derived largely from the Mir Space Station Core Module. Figure 10 below shows how the Service Module connects to the FGB.

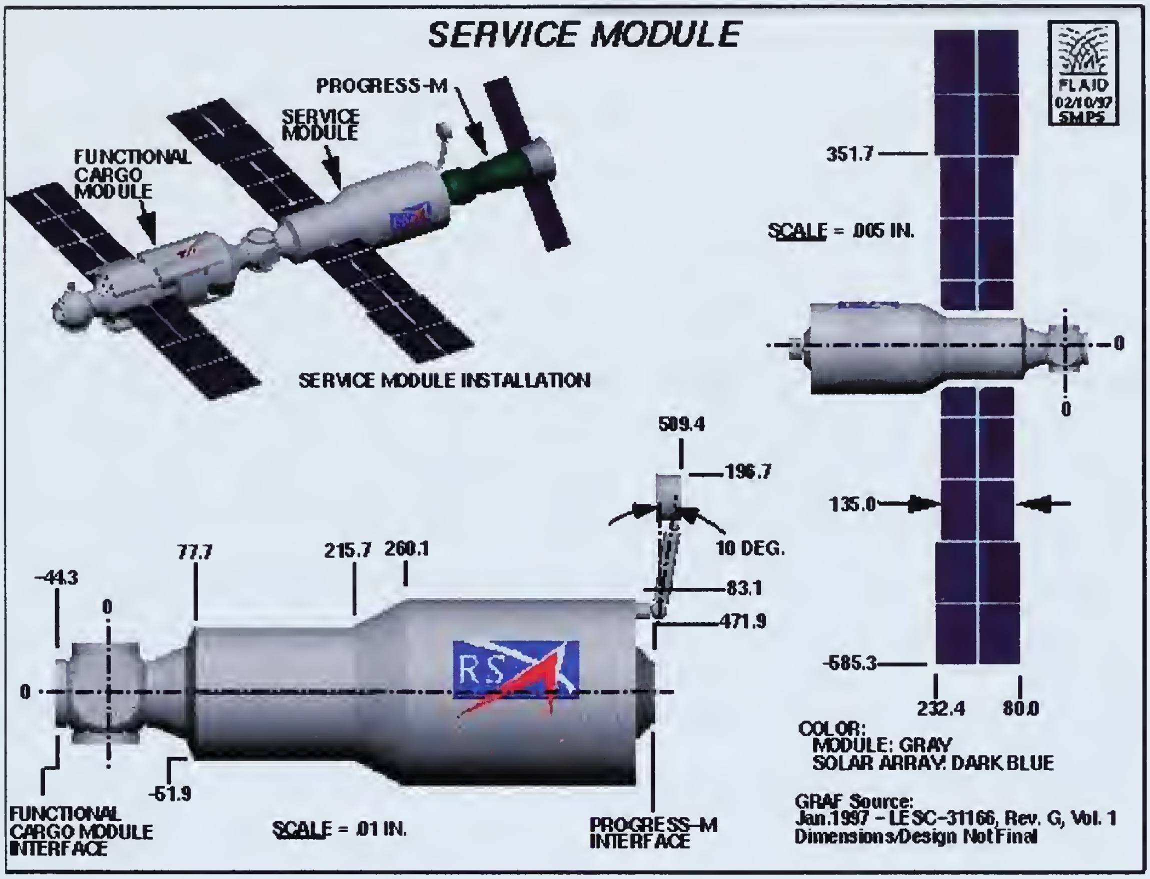

Figure 10. Another perspective of the Service Module. Note its relationship to the FGB. The Node 1 adapter joins the FGB and Service Module. The Progress M is the Russian logistics refueling and servicing spacecraft.

The Service Module's solar arrays span almost 100 feet and it is over 40 feet long. The SM is designed to have four docking ports, with the aft docking port consisting of a

probe and cone mechanism for the Progress and Soyuz re-supply spacecraft. The Service Module is a rather spacious (by current space standards) craft.

The living quarters include sleeping areas, a refrigerator and freezer, toilet and dinner table. In the Service Module there are 14 windows, with one window in each crew area. There will also be a NASA-supplied exercise cycle and treadmill. In the final configuration of the International Space Station, the Russian supplied segments of the FGB and Service Module represent over one third of the orbiting mass. These two components, when joined together by the Node 1 coupler, will form the core around which the rest of the space station is assembled. It is not melodramatic to conclude that without these components, there will be no International Space Station as currently envisioned. For better or for worse, the fate of the International Space Station is tied to that of the Russian space industry and the RSA.

C. CONCLUSION

1. The Role of the MTCR and the ISS

The United States has prudently sought to stabilize the RSA and Russian space industry through two high profile agreements. The Missile Technology Control Regime (MTCR) welcomed Russian participation in their efforts to control

the proliferation of technologies which might facilitate the spread of weapons of mass destruction (WMD). Russian launch vehicle prowess, if not its relative cheapness and effectiveness, could be a prominent contributor to the spread and lethality of WMD. MTCR provides the moral imperative for Russian participation. Merging Russian technologies in the ISS ensures financial and technical commitment for the RSA and Russian space industries. Figure 11 below shows the final ISS configuration.

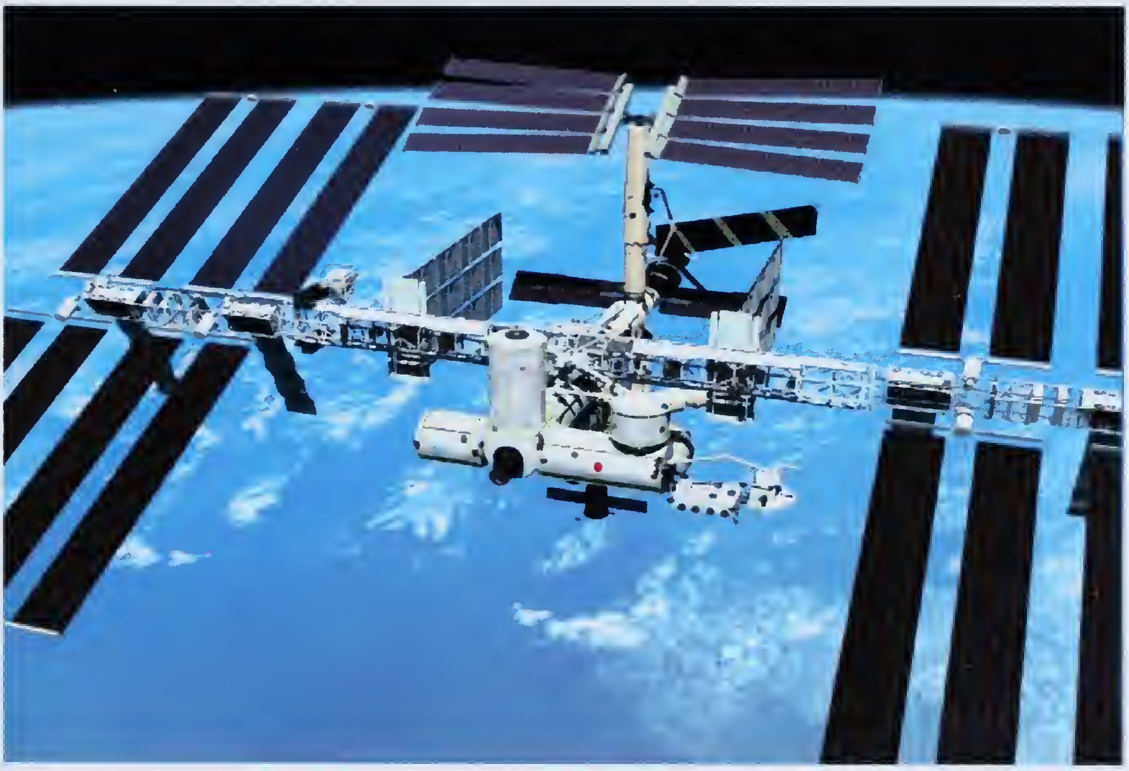

Figure 11. Artist's conception of the final configuration of the International Space Station. The Russian FGB-Service Module link are somewhat hidden. The link is amidship, perpendicular to the solar array station and the US/ESA/Japanese complex in the foreground of the picture.

The ISS represents a successful link between national security and space policies. It is not merely a giveaway to the Russians, nor should it be viewed as such: the Russians can and will render significant and highly credible contributions to the ISS. The Russian ability to launch massive payloads into a LEO orbit with the Proton launch vehicle will dramatically limit operating costs for the space station. Perhaps more importantly, Russian commitment to the ISS will provide a sustained outlet for Russian scientific and technical expertise. The Service Module and Functional Cargo Block (FGB) represent over one third of the total mass of the space station and are the architectural hub upon which the rest of the space station will be assembled. Russia and the RSA will critically support the International Space Station. The ISS is as necessary for Russia and the RSA as the RSA and Russia are for the ISS.

V. CONCLUSIONS

A. OPTIMISM AND JOINT COOPERATION

The United States is now working closely with the Russian Federation in areas and endeavors that span the continuum of strategic policy. The area of joint space cooperation, whether commercial or governmental, bears continuous scrutiny. This paper examined the RSA space program and assessed it, making note of possible advantages in working with the RSA, as well as noting possible hazards. Certainly, assessing and tracking the overall percentage of successful launches from Baikonur, as well as Baikonur's share of all global launches, offer the clearest insight into the RSA's global launch support posture and viability. The total annual value of billed services RSA charges its customers for use of Baikonur, and the rate at which this value changes, also will give clear insight into the overall health and trends of launch services conducted by the RSA.

B. THE PROTON

The Proton has the heaviest payload capacity currently being offered on the commercial market. Because of its extended track record of success and reliability, it has quickly established itself as a major player in the international launch vehicle market.

C. LACK OF VIABLE ALTERNATIVES

The most obvious alternative to an ISS partnership with the Russians is no partnership whatsoever. Assuming RSA responsibilities would lessen ISS cost overruns and schedule slippage. But the costs entailed in redesigning the ISS without the benefit of the Proton and the launch facilities at Baikonur would quickly overtake any cost overruns currently attributed to the RF. The ISS would have to be significantly redesigned and the delays resulting from this redesign would easily be measured in years and not months. The ISS would also have to forego unique Russian insight into the effects of microgravity and long duration space activity.

Removing the ISS as technology proliferation leverage over the Russians and the RSA would force the international community to rely entirely on the MTCR accords and the good faith of a diminished RSA to police Russian space and missile technology proliferation. Yeltsin has empowered the RSA to control all aspects of its space and missile technology. The ISS will also offer Russian space and missile personnel a meaningful alternative to proliferation. Partnership with the RSA in the ISS is the only effective way to engage and monitor the Russians' proliferation control efforts.

D. WHY COMMITMENT TO RUSSIA AND THE RSA MATTERS

The opportunities offered by a partnership with the Russians and the RSA in the International Space Station are unique and of the utmost importance to the US. Russian heavy lift capability as represented by the Proton and the launch flexibility potential of the Baikonur Cosmodrome are irreplaceable; without Russian participation in the ISS the entire scope and design goals of the space station would have to be thoroughly redesigned.

Partnership with the Russians in the ISS also offers distinct scientific and technical advantages to the ISS as well as the US commercial space industry. The Russians have unique experience in the effects of long duration space exposure on the human body. Russian expertise in material science applications in space as well as microgravity experiences are vital to the success of the experiments planned for the ISS.

From a strategic perspective, a partnership with the RSA in the ISS may be the most effective, practical means whereby Russia's success at controlling the proliferation of its space and missile technology can be monitored with any degree of certainty. The RSA now has the sole responsibility to control Russian technology proliferation. The US must take advantage of the ISS partnership to constructively engage the RSA in its proliferation control efforts. The ISS partnership is an open door to witness RF proliferation control efforts at very close range. Closing this window of opportunity would leave the MTCR as the sole means by which to induce Russian compliance with proliferation control. The US must not limit its range of options and degrees of freedom; every avenue through which to monitor and aid Russian proliferation control must be pursued.

The US should remain committed to working with the RSA both on a multilateral level, and within the management structure of the International Space Station Alpha. While being mindful of the constraints and hazards of the RF political, legal, and technological environment, the US should actively pursue and incorporate the RSA's distinct operational and technical advantages into its own space program. The 21st century is just around the corner, and how the US balances its space commitments with the advantages and hazards of working with the RSA may significantly influence the extent and nature of our future space accomplishments. Space offers unlimited opportunities for the US and the RF. How these opportunities are managed and pursued will truly determine each country's space legacy for the next millenium.

BIBLIOGRAPHY

AP Wire Services, Iridium Launch From Russia Successful, April 7th, 1998.

Ardayev, Vladimir. "Kazakhstan: Depressing Landscape With Fireworks," *Isvetiya* (Moscow), 3 November 1994, page 4. (Foreign Broadcast Information Service translated text.)

Baksian, Douglas. *India Satellite Launch,* VOA News Report, 29 August 1997.

De Selding, Peter B. "Proton Pricing Spurs Complaints," *Space News,* 9 January 1995.

Dmitriyev, Petr. "Rocket Builders Break Their Silence. Space Station Assembly Finally Postponed Officially," *Moscow Nezavisimaya Gazeta,* April 7 1998.

Federation of American Scientists, *Space Launch Vehicles,* [http://www.fas.org/spp/guide/russia/launch].

Gerth, Jeff. "Satellite Maker Gave Report to China Before Telling U.S.", *New York Times*, 19 May 1998.

Golotyuk, Yuriy. *Russia: Space Agency to Acquire 'Special Service' Arm.* FBIS translation of Moscow Russkiy Telegraf, 15 May 98.

Griffin, Jennifer. Untitled, VOA News Report, 26 March 1997.

Harford, James. *Korolev: How One Man Masterminded the Soviet Drive to Beat America to the Moon* (New York: John Wiley & Sons, Inc, 1997).

Harvey, Brian. *The New Russian Space Programme (New York:* John Wiley & Sons, Inc, 1996).

Henry, John C. "Russian Financial Woes Put Space Station in Jeopardy," *Houston Chronicle,* 23 April 1998. Also refer to [http://www.chron.com:80/cgi-bin/auth/story.mpl/content/chronicle/nation].

[http://www.fas.org/asmp/campaigns/missiles/1997 plenary info.html].

[http;//station.nasa.gov/science]

International Partner Cooperation - Russian Space Agency, [http://station.nasa.gov/reference/status/rsa.html].

Khozin, Grigori S. *Russian Space Commercialization - getting the banks involved,* Space Policy 1996, Volume 12, Number 3.

Larson, Wiley J. and Wertz, James R. editors*, Space Mission Analysis and Design* (Torrance, California: John Wiley & Sons, Inc, 1995).

Laursen, Eric F. and Voce, John E. *The Proton Launch Vehicle System Current Status*, 16th International Communications Satellite System Conference, February 1996.

Missile Technology Control Regime Plenary Meeting, Press Release. Tokyo, November 6th, 1997.

Panholzer, Rudy. Chairman of the Space Systems Academic Group (SSAG) at the Naval Postgraduate School (NPS), Monterey California in an interview on April 20th, 1998.

Pike, John. *Ralpha, Russian American Space Cooperation*, 10 December 1993, at [http://www.fas.org/spp/eprint/jp 931210.htm].

Report of the Cost Assessment and Validation Task Force on the International Space Station, NASA Advisory Council, [http://www.nasa.gov/cavtf/cavtf 1.html].

Russian Federation President. *Decree Establishing the Russian Space Agency*, Moscow, February 1992. Boris Yeltsin.

Sinelshchikov, M. V. "Russian Launch Vehicles' State of the Art and Lines of their Improvement, ESA pub, SP-362, March 1994.

Specter, Michael. "Where Sputnik Once Roared into History, Hard Times take Hold," *The New York Times*, 21 March 1995.

Tarasenko, M. V. *Current Status of the Russian Space Program,* Space Policy, Volume 12, Number 1, February 1996.

[http;//station.nasa.gov/science]

International Partner Cooperation - Russian Space Agency, [http://station.nasa.gov/reference/status/rsa.html].

Khozin, Grigori S. *Russian Space Commercialization - getting the banks involved,* Space Policy 1996, Volume 12, Number 3.

Larson, Wiley J. and Wertz, James R. editors, *Space Mission Analysis and Design* (Torrance, California: John Wiley & Sons, Inc, 1995).

Laursen, Eric F. and Voce, John E. *The Proton Launch Vehicle System Current Status*, 16th International Communications Satellite System Conference, February 1996.

Missile Technology Control Regime Plenary Meeting, Press Release. Tokyo, November 6th, 1997.

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Pike, John. *Ralpha, Russian American Space Cooperation*, 10 December 1993, at [http://www.fas.org/spp/eprint/jp_931210.htm].

Report of the Cost Assessment and Validation Task Force on the International Space Station, NASA Advisory Council, [http://www.nasa.gov/cavtf/cavtf_1.html].

Russian Federation President. *Decree Establishing the Russian Space Agency*, Moscow, February 1992. Boris Yeltsin.

Sinelshchikov, M. V. "Russian Launch Vehicles' State of the Art and Lines of their Improvement, ESA pub, SP-362, March 1994.

Specter, Michael. "Where Sputnik Once Roared into History, Hard Times take Hold," *The New York Times*, 21 March 1995.

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   Naval Postgraduate School
   411 Dyer Rd.
   Monterey, CA 93943

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